THE
STEAM-BOILER CATECHISM

A PRACTICAL BOOK FOR

Steam Engineers, and for Firemen, Owners and Makers of Boilers of any Kind.

Covering the Properties of Steam and of Fuels, and the Theory and practice of Designing, Constructing, Setting, Connecting, Testing, Firing and Repairing.

BY

ROBERT GRIMSHAW, M. E.,

Past Pres. James Watt Association, No. 7 of N.Y., N.A.S.E.; Member Fulton Council, No. 1, A.O.S.E.; Ed. "Power and Transmission;" Author of "Steam-Engine Catechism." "Pump Catechism," "Plumbing Catechism," Preparing for Indication," "Hourly Log Book," "Square Root Made Easy," and other Practical Works.

PROFUSELY ILLUSTRATED.

Second Edition.

NEW YORK:
WOOLFALL, CLARK & ZUGALLA,
119 & 121 NASSAU STREET.

TO

THOSE BOILER OWNERS

WHO BELIEVE IN PAYING A FAIR PRICE FOR
FIRST-CLASS BOILERS AND SETTINGS,

AND

IN HIRING TO FIRE AND RUN THEM,

COMPETENT MEN AT GOOD WAGES,

THIS BOOK IS DEDICATED.

CONTENTS.

CONTENTS.

PREFACE.

This Catechism, like its companions, the "Pump Catechism," and the two volumes of the "Steam Engine Catechism," is not intended as a means of greatly instructing those who are expert in constructing, or efficient in running the appliances of which it treats. It may, however, serve the well-posted as a handy reminder at times when, from haste, or lapse of time, or mental pressure, the memory is not wholly reliable; and to the learner and the inexperienced it should serve as a useful reference and a convenient source of information. It aims to be, while rs nearly completeas its size admits, abso lutely accurate, and unmistakably direct, simple and clear. Where good usages or expert opinions differ, both sides of a question are generally presented.

I offer no apology for mentioning some patented boilers and appliances, and not others. Nearly every maker of whom I had the address was offered opportunity of representation in the body of the work without charge, direct or indirect.

PREFACE.

The examination questions of the Canadian, New York and Philadelphia licensing boards are distributed throughout the work under their proper headings, all except those personal questions which refer to candidate's names, time of service, etc., and a few of the purely arithmetical matters.

I do not claim any originality in this book. A man's knowledge in steam engineering is not invented; it is like geography, the sum of the personal knowledge of thousands of others.

It is not to be supposed or expected that it will answer every question which might be asked, concerning a steam boiler. It does answer all that have occurred to me, or of which I have a record as having been asked me.

As with my other Practical Catechisms, I shall take great pleasure in answering by mail, where possible, and when stamp is enclosed, questions not answered in this book; and shall add such questions and their answers, (omitting of course, correspondent's names,) to future volumes or editions should they be called for. The reader is especially requested to consult the index.

ROBERT GRIMSHAW.

June, 1888.

THE STEAM-BOILER CATECHISM.

DEFINITIONS AND PRINCIPLES.

Q What is steam?

A. A thin vapor, or fluid, condensible by cold, and elastic under compression; and which is one of the three states (ice, water and steam) in which water exists, according to temperature.

Q. What is a vapor?

A. Correctly speaking, a temporary gaseous or air-like state of some substance, the ordinary condition of which is that of a liquid or solid.

Q. What is a fluid?

A. "A substance whose parts change their relative positions on the slightest pressure, and therefore retain no definite form."—*Webster*.

Q. What is the difference between a liquid and a fluid?

---

*Portions of these definitions, common to the study of both the steam engine and the steam boiler, are, almost of necessity, quoted, nearly verbatim from the two volumes of the author's Steam Engine Catechism. This parallelism, however, extends over but a very few pages.

A. Every liquid is a fluid; every gas or vapor is a fluid; in fact, therefore, everything which is not solid is fluid; but every fluid is not a liquid. This is on the same principle that "all beef is meat, but all meat is not beef." Water is a liquid and also a fluid; steam is a vapor and also a fluid.

PROPERTIES OF STEAM.

Q. What is one of the most marked and useful characteristics of steam?

A. Its tendency to expand, decreasing its pressure in about the same ratio as it increases its volume.

Q. How is this characteristic useful to us?

A. By its pressure it may be made to traverse long lines of pipe, and at a distance from where it is generated, either do what is known as "mechanical work" or act as a heating medium.

Q. What is the color of steam?

A. It has no color preceptible to the eye. When it escapes into the atmosphere and is partly condensed, it assumes at first a bluish tinge and then a whitish color due to the reflection of the light from the particles of water.

Q. What is the temperature of steam?

A. The temperature or "sensible heat" of steam varies with the conditions. Steam formed from water under the ordinary atmospheric pressure (14.7 lbs. per square inch at sea level) has a temperature of 212° Fahrenheit = 100° Centigrade. Confined so that expansion is impossible, it is generated at a temperature corresponding to the pressure or tension; that is, the greater the tension the greater the temperature; or putting it the other way, as the temperature is increased the pressure rises, so long as there is more water, in contact with the steam, from which to make more steam and thus increase the pressure. It may be maintained at a constant temperature under constant pressure so long as the generation continues.

I give a table showing the temperature in degrees Fahrenheit, corresponding to various tensions; the tensions being expressed in pounds per square inch, but *above vacuum*, not above atmosphere, or "by the gauge."

PRESSURE AND TEMPERATURE OF SATURATED STEAM—REGNAULT.

Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pressure per sq. in.	Temperature degrees Fahr.
1	102.1	20	228.	40	267.3
2	126.3	21	230.6	41	268.7
3	141 6	22	233.1	42	270.2
4	153.1	23	235.5	43	271.6
5	162.3	24	237 8	44	273.
6	170.2	25	240.1	45	274.4
7	176.9	26	242 3	46	275.8
8	182.9	27	244.4	47	277.1
9	188.3	28	246.4	48	278.4
10	193.3	29	248.4	49	279.7
11	197.8	30	250.4	50	281.
12	202.	31	252.2	51	282.3
13	205.9	32	254.1	52	283.5
14	209.6	33	255.9	53	284.7
14.7	212.	34	257.6	54	285.9
15	213.1	35	259.3	55	287.1
16	216.3	36	260.9	56	288.2
17	219.6	37	262.6	57	289.3
18	222.4	38	264.2	58	290.4
19	225.3	39	265.8	59	291.6

PRESSURE AND TEMPERATURE OF SATURATED STEAM—REGNAULT.

Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pres sure per sq. in.	Temperature degrees Fahr.
60	292.7	80	312.	100	327.9
61	293.8	81	312.8	101	328.5
62	294.8	82	313.6	102	329.1
63	295.9	83	314.5	103	329.9
64	296.9	84	315.3	104	330.6
65	298.	85	316.1	105	331.3
66	299.	86	316.9	106	331.9
67	300.	87	317.8	107	332.6
68	300.9	88	318.6	108	333.3
69	301.9	89	319.4	109	334.
70	302.9	90	320.2	110	334.6
71	303.9	91	321.	111	335.3
72	304.8	92	321 7	112	336.
73	305.7	93	322.5	113	336.7
74	306.6	94	323.3	114	337.4
75	307.5	95	324.1	115	338.
76	308.4	96	324.8	116	338.6
77	309.3	97	325.6	117	339.3
78	310.2	98	326.3	118	339.9
79	311.1	99	327.1	119	340.5

PRESSURE AND TEMPERATURE OF SATURATED STEAM—REGNAULT.

Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pressure per sq. in.	Temperature degrees Fahr.	Absolute pressure per sq. in.	Temperature degrees Fahr.
120	341.1	141	353.5	220	389.9
121	341.8	142	354.	230	393.8
122	342.4	143	354.5	240	397.5
123	343.	144	355.	250	401.1
124	343.6	145	355.6	260	404.5
125	344.2	146	356.1	270	407.9
126	344.8	147	356.7	280	411.2
127	345.4	148	357.2	290	414.4
128	346.	149	357.8	300	417.5
129	346.6	150	358.3	350	430.1
130	347.2	155	361.	400	444.9
131	347.8	160	363.4	450	456.7
132	348.3	165	366.	500	467.5
133	348.9	170	368.2	550	477.5
134	349.5	175	370.8	600	487.
135	350.1	180	372.9	650	495.6
136	350.6	185	375.3	700	504.1
137	351.2	190	377.5	800	519.5
138	351.8	195	379.7	900	533.6
139	352.4	200	381.7	1000	546.5
140	352.9	210	386.		

Q. Should the quantity of steam be estimated by weight or by volume; and why?

A. Steam should always be estimated by weight because the volume of a vesselful of steam is no indication of what it is capable of doing in the way of heating or producing mechanical work; and the same quantity of steam may change its volume; while of course it cannot change its weight.

Q. What is the weight of a cubic foot of dry steam?

A. That depends upon its pressure. The greater the pressure, the greater the weight of steam compressed into a cubic foot. The following table gives the weight of one cubic foot of dry steam at various pressures per square inch, *above vacuum; not above atmosphere or "by the gauge."* It also gives the volume in cubic feet, of one pound of steam at these pressures; and the corresponding temperatures. (At high temperatures "dry" or "saturated" steam is denser than "gaseous" or "superheated," which latter is 0.622 that of air.)

Pressure *ab. vacuum* lbs. p'r sq. in.	Temperat're Fahrenheit degrees	Weight of 1 c'bic ft. in lbs. avoirdupois.	Volume of 1 pound in cubic ft.	Pressure *ab. vacuum* lbs p'r sq. in.	Temperat're Fahrenheit degrees.	Weight of 1 c'bic ft. in lbs avoirdupois.	Volume of 1 pound in cubic ft.
1	102.1	.0030	330.36	35	259.3	.0858	11.65
2	126.3	.0058	172.08	36	260.9	.0881	11.34
3	141.6	.0085	117.52	37	262.6	.0905	11.04
4	153.1	.0112	89.62	38	264.2	.0929	10.76
5	162.3	.0138	72.66	39	265.8	.0951	10.51
6	170.2	.0163	61.21	40	267.3	.0974	10.27
7	176.9	.0189	52.94	41	268.7	.0996	10.03
8	182.9	.0214	46.69	42	270.2	.1020	9.81
9	188.3	.0239	41.79	43	271.6	.1042	9.59
10	193.3	.0264	37.84	44	273.0	.1065	9.39
11	197.8	.0289	34.63	45	274.4	.1089	9.18
12	202.0	.0314	31.88	46	275.8	.1111	9.00
13	205.9	.0338	29.57	47	277.1	.1133	8.82
14	209.6	.0362	27.61	48	278.4	.1156	8.65
14.7	212.0	.0380	26.36	49	279.7	.1179	8.48
15	213.1	.0387	25.85	50	281.0	.1202	8.31
16	216.3	.0411	24.32	51	282.3	.1224	8.17
17	219.6	.0435	22.96	52	283.5	.1246	8.04
18	222.4	.0459	21.78	53	284.7	.1269	7.83
19	225.3	.0483	20.70	54	285.9	.1291	7.74
20	228.0	.0507	19.72	55	287.1	.1314	7.61
21	230.6	.0531	18.84	56	288.2	.1335	7.48
22	233.1	.0555	18.03	57	289.3	.1364	7.36
23	235.5	.0580	17.26	58	290.4	.1380	7.24
24	237.8	.0601	16.64	59	291.6	.1403	7.12
25	240.1	.0625	15.99	60	292.7	.1425	7.01
26	242.3	.0650	15.38	61	293.8	.1447	6.90
27	244.4	.0673	14.86	62	294.8	.1469	6.81
28	246.4	.0696	14.37	63	295.9	.1493	6.70
29	248.4	.0719	13.90	64	296.9	.1516	6.60
30	250.4	.0743	13.46	65	298.0	.1538	6.49
31	252.2	.0766	13.05	66	299.0	.1560	6.41
32	254.1	.0789	12.67	67	300.0	.1583	6.32
33	255.9	.0812	12.31	68	300.9	.1605	6.23
34	257.6	.0835	11.97	69	301.9	.1627	6.15

Pressure *ab. vacuum* lbs. p'r sq in.	Temperat're Fahrenheit degrees.	Weight of 1 c'bic ft. in lbs avoirdupois.	Volume of 1 pound in cubic feet.	Pressure *ab. vacuum* lbs. p'r sq. in.	Temperat're Fahrenheit degrees.	Weight of 1 c'bic ft. in lbs avoirdupois	Volume of 1 pound in cubic ft.
70	302.9	.1648	6.07	106	331.9	.2435	4.11
71	303.9	.1670	5.99	107	332.6	.2456	4.07
72	304.8	.1692	5.91	108	333.3	.2477	4.04
73	305.7	.1714	5.83	109	334.0	.2499	4.00
74	306.6	.1736	5.76	110	334.6	.2521	3.97
75	307.5	.1759	5.68	111	335.3	.2543	3.93
76	308.4	.1782	5.61	112	336.0	.2564	3.90
77	309.3	.1801	5.54	113	336.7	.2586	3.86
78	310.2	.1826	5.48	114	337.4	.2607	3.83
79	311.1	.1843	5.41	115	338.0	.2628	3.80
80	312.0	.1869	5.35	116	338.6	.2649	3.77
81	312.8	.1891	5.29	117	339.3	.2652	3.74
82	313.6	.1913	5.23	118	339.9	.2674	3.71
83	314.5	.1935	5.17	119	340.5	.2696	3.68
84	315.3	.1957	5.11	120	341.1	.2728	3.65
85	316.1	.1980	5.05	121	341.8	.2759	3.62
86	316.9	.2002	5.00	122	342.4	.2780	3.59
87	317.8	.2024	4.94	123	343.0	.2801	3.56
88	318.6	.2044	4.89	124	343.6	.2822	3.54
89	319.4	.2067	4.84	125	344.2	.2845	3.51
90	320.2	.2089	4.79	126	344.8	.2867	3.49
91	321.0	.2111	4.74	127	345.4	.2889	3.46
92	321.7	.2133	4.69	128	346.0	.2911	3.44
93	322.5	.2155	4.64	129	346.6	.2933	3.41
94	323.3	.2176	4.60	130	347.2	.2955	3.38
95	324.1	.2198	4.55	131	347.8	.2977	3.3[illegible]
96	324.8	.2219	4.51	132	348.3	.29[illegible]9	3.33
97	325.6	.2241	4.46	133	348.9	.3020	3.[illegible]1
98	326.3	.2263	4.42	134	349.5	.3040	3.[illegible]9
99	327.1	.2285	4,37	135	350.1	.3060	3.27
100	327.9	.2307	4.33	136	350.6	.3080	3.[illegible]5
101	328.5	.2329	4.29	137	351.2	.3101	3.22
102	329.1	.23[illegible]1	4.25	138	351.8	.3121	3.[illegible]0
103	329.9	.2378	4.21	139	352.4	.3142	3.18
104	330.6	.2393	4.18	140	352.9	.3162	63.1
105	331.3	.2414	4.14				

Q. What is saturated steam?

A. Saturated steam is that which is generated at the maximum density and pressure corresponding to its temperature.

Q. Is saturated steam capable of vaporizing more water into the same space unless the temperature be raised?

A. No.

Q. What then is "saturation" as applied to steam?

A. Saturation is "the normal condition of steam generated in contact with a store of water."

Q. In saturated steam, are the same density and the same pressure always to be found in conjunction with the same temperature?

A. Yes.

Q. What is the effect of a change of temperature, in saturated steam, in contact with water?

A. It is condensed if the temperature falls, and more water is evaporated if the temperature rises.

Q. Is dry steam any hotter than saturated?

A. No.

HEAT AND TEMPERATURE.

Q. When have two bodies the same temperature?

A. When neither one gives out heat to the other

Q. Does not this imply that they have the same amount of heat in them?

A. No. Their capacities for storing heat may be different. Starting at the same temperature, one may take twice as much heat to bring it to a given temperature, as the other.

Q. What is the usual effect of increase of temperature on a body?

A. To expand it.

Q. Any exception?

A. Yes; water in going from 32 degrees and 39 degrees F., contracts in volume; above 39 degrees it expands.

Q. In a given increase of temperature, which expands the most, liquids or solids?

A. Liquids.

Q. Do liquids expand regularly, with regular increments of temperature?

A. No; they expand more rapidly at a high than at a low temperature.

Q. What is evaporation?

A. The conversion of a liquid into a

gas or vapor, quietly and without bubbling.

Q. What is ebullition or boiling?

A. Conversion of a liquid into a gas or vapor in a violent manner, with bubbles.

Q. What facilitates evaporation and ebullition?

A. Removal of the whole or part of the air pressure. ("Facilities" is a better word than "increases.")

Q. What is the spheroidal state?

A. That condition of water or other liquid, in which, when put on a very hot surface, it does not wet the latter but rests on a cushion of steam.

Q. What has this to do with steam boilers and practical engineering?

A. This:—that when the steam cushion breaks, the whole mass of water may suddenly be turned into steam; this might happen in a steam boiler with low water and cause an explosion.

Q. At what temperature does water take on the "spheroidal state?"

A. At 340 degrees F.

Q. At what temperature does it again touch the surface and commence boiling?

A. 288 degrees F.

Q. What is latent heat?

A. The heat which a body will absorb without showing any increase of temperature; as the heat taken up, and stowed away by water at 212 degrees before it becomes steam at 212 degrees.

Q. Has steam much latent heat?

A. More than any other gas or vapor; that is, it takes more heat to vaporize 1 lb. of water, than 1 lb. of any other liquid.

Q. How can you get work into water or steam?

A. Only by heating it.

Q. How can you get work out of steam?

A. Only by cooling it.

Q. Then the engine which cools the steam the most is the best?

A. Yes, if that cooling is *by doing work*. The engine which expands steam from 100 to 20 lbs., is doing more work than the one which expands only from 100 to 50 lbs.

Q. How is heat transferred or communicated?

A. In three ways; radiation, conduction, convection.

Q. What is radiation?

A. The passage of heat from a body, in diverging straight lines through air or vacuum; as from the surface of the coals in a furnace to the shell, or to your face when you open the door and look in.

Q. What is conduction?

A. The passage of heat through a substance, by being passed along from one atom to another, without any motion among the atoms; as, when one end of a short bar of iron is red hot, the other end tends to get hot too; as the heat is passed from one side of a boiler sheet to the other.

Q. What is convection?

A. Carrying heat from one place to another by currents of liquid or of gas or vapor; as where the water at the surface in a boiler is heated by currents from the bottom.

Q. Do all substances conduct heat alike?

A. No; some pass it along very slowly and imperfectly and are said to be poor conductors or non-conductors.

Q. Name some poor conductors.

A. Glass, wool, feathers, air, water.

Q. Name some good ones in the order of their excellence.

A. Among the metals:

	Relative conducting power.
Silver	100.0
Copper	74.8
Gold	54.8
Brass	24.
Tin	15.4
Steel	10.3
Iron	10.1
Lead	7.9

Q. What is the latent heat of steam at 212 degrees F?

A. From 996 degrees to 998 degrees F.

Q. How many feet above the sea level must you go in order to have water boil at 211 degrees F?

A. 550.

Q. At what temperature will water boil in a vacuum?

A. 67 degrees F.

Q. Is it possible for steam at say 10 pounds to be so highly superheated as to char the wooden lagging of a boiler?

A. It has been known to be so superheated.

Q. Can steam which is not superheated lose any part of its heat without being condensed?

A. No.

PRESSURES.

Q. In what direction is the steam pressure in a boiler exerted?

A. In all directions.

Q. In what direction is the pressure due to the weight of the water in a boiler exerted?

A. Towards the shell.

Q. Is there most pressure at the top or at the bottom of a boiler?

A. From the top down to the water-level, the pressure is the same at every height. From the water-level down to the bottom, the pressure increases as you go downwards, the radial pressure being increased by the "head" of the water.

Q. How is boiler pressure estimated?

A. In pounds avoirdupois per square inch of boiler surface, or else in atmospheres.

Q. How much is an atmosphere?

A. Under ordinary conditions, at the sea level, 14.7 lbs. per square inch.

Q. From what point is boiler pressure reckoned?

A. From the pressure of the atmosphere, upwards; the base being 14.7 lbs. per square inch above vacuum.

Q. How many times 15 lbs. per square inch by the gauge is 60 lbs. per square inch?

A. About 2½; as 15 lbs. per square inch by the gauge, is really 29.7 lbs.; and 60 lbs. is really 74.7 lbs. above vacuum.

Q. Then in reckoning boiler pressure, would a boiler to stand 30 lbs. by the gauge be more than half as strong as one to have to stand 60 lbs.?

A. Most decidedly *not!* When it comes to bursting strength, the pressure of the atmosphere is counted off both sides of the shell, inside and out.

Q. As you go up from the sea level, is the air-pressure outside of a boiler increased or diminished?

A. Diminished.

Q. Just before a rain is the atmospheric pressure greater or less than in clear weather?

A. Less. The barometer is said to fall before a rain; that means that in one which has a mercurial column, the pressure of the air, holding the mercury up in the tube, lessens.

Q. How much volume of steam will one cubic inch of water make?

A. Nearly one cubic foot at 212 degrees, or just atmospheric pressure.

Q. When steam boilers were first used, how did the pressures run?

A. Under 10 lbs. per square inch above atmosphere, up to 50 or 60 years ago.

Q. What pressures are now most usually carried?

A. 60 to 80 lbs.

Q. What is the maximum used?

A. About 180 lbs. for locomotives is the highest frequently met with.

Q. What objections to pressures over 200 or 250 lbs?

A. Difficulty of keeping joints tight; destruction of most lubricants used in the engine.

Q. What lubricant is absolutely unchangeable by heat?

A. Graphite (plumbago, blacklead).

Q. What are the advantages of high pressure steam?

A. It requires smaller engines and smaller boilers for a given horse power; besides which it utilizes a greater proportion of the heat put into it than low pressures do.

MATERIALS.

Q. What materials are used in the construction of boilers?

A. Cast iron, wrought iron, steels of various sorts; copper, brass and other copper alloys.

Q. What is the one most frequently used?

A. Wrought iron; although mild steel appears to be coming in rapidly.

Q. Where is copper used?

A. In marine boilers and in locomotive fire boxes. In this country the copper marine boilers are mostly in government vessels. Copper fire boxes are not known in the U. S.

A. What are the advantages of copper?

A. Homogeneity; high conducting power for heat; durability; resistance to corrosion; value as scrap.

Q. What are the disadvantages?

A. High first cost; softness; low tensile strength.

Q. What are the advantages of cast iron for boiler construction?

A. Cheapness; resistance to corrosion; freedom from blistering; immunity from strains on account of changes of temperature; high conducting power as compared with wrought iron; parts made of it need no bracing; ease of replacing defective sections.

Q. What are the objections to cast iron for boilers?

A. It is treacherous; gives no warning before letting go, parts are not uniformly strong; the necessarily small parts cause priming.

Q. What is the tensile strength of ordinary iron castings?

A. Varies both sides of 15,000 lbs. per square inch.

Q. What is its elastic limit?

A. About one-third its bursting strength.

Q. What are the advantages of wrought iron for boilers?

A. High tenacity and elasticity; ease of flanging; familiarity in working it

on the part of workmen all over the world.

Q. What are its disadvantages?

A. Liability to blister.

Q. What should be the minimum tensile strength of wrought iron for boiler making?

A. 45,000 lbs. per square inch.

Q. What are the advantages of mild steel in boiler work?

A. Homogeneity; high tensile strength; malleability; ductility; freedom from blisters.

Q. What objections to steel?

A. Requires a better grade of workmen on it than iron, especially in making the rivet holes and in flanging

Q. What should be the minimum tensile strength of steel for boiler work?

A. There is properly no minimum There should be comparatively low tensile strength; it is homogeneity and toughness that are desired.

Q. Is steel injured by drilling?

A. No.

Q. Is it injured by punching?

A. Yes, about one-third.

Q. How can its nature be restored after punching?

A. By annealing, or by reaming out the borders of the punched hole.

Q. Will good material all through a boiler insure long life?

A. No, because it may be improperly designed, and there may be from this cause unequal expansion and contraction, etc., which will tend to make it last but a short time.

KINDS OF BOILERS

Q. What is a steam boiler?

A. Properly a *water* boiler. A supposedly strong and safe closed vessel, containing water, and in which heat is applied by a furnace or otherwise, for the purpose of generating steam under pressure, from the water to which the heat is applied.

Q How many kinds of boilers are there?

A. That depends on how you wish to classify them as regards their shape, their use, or what.

Q. As regards their shape, can you name some of the types?

A. Spherical, cylindrical, egg-shaped, wagon top, haystack, etc.

Q. What was one of the earliest form of boilers?

A. Spherical, of cast iron, with fire underneath.

Q. What followed this?

A. A vertical cylinder with flat bottom and curved top, and having masonry flues about it.

Q. How was this improved?

A. By arching in the bottom.

Q. What followed this?

A. The horizontal cylindrical type.

Q. What followed this?

A. The "wagon" boiler of Watt.

Q. What objection to this?

A. Tendency to change its shape in spite of elaborate staying.

Q. Describe the wagon boiler.

A. It has its upper portion nearly cylindrical in shape, but having a box-like projection running its whole length below it.

Q. What supplanted the "wagon?"

A. The "haystack," or "balloon," having well lined sides and hemispherical top; sometimes made 20 feet in diameter.

Q. What objections to this?

A. Want of heating surface; liability to give way in the bottom.

FIG. 1.—TWO-FLUE BOILER.

FIG. 2.—"ERIE CITY" TEN-FLUE TYPE.

Q. What is the simplest type of cylindrical boiler?

A. Plain horizontal cylinder, with

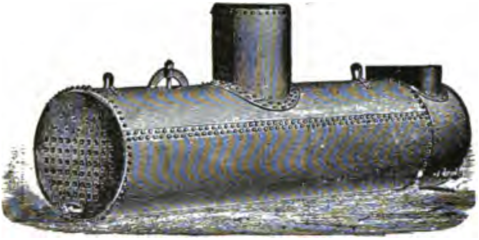


FIG. 3—LONG SHEET MULTITUBULAR FLUE TYPE. (Erie City Iron Works.)

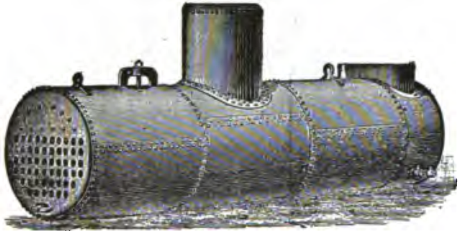


FIG. 4.—MULTITUBULAR (SHORT SHEET) TYPE. (Erie City Iron Works.)

flat, cambered, or hemispherical ends.

Q. What was another advance on the single large flue boiler, other than placing the furnace in the flue?

A. Passing the gases of combustion through two large parallel flues, instead of one. (See Fig. 1)

Q. Into what did the two-flue boiler develop?

FIG. 5.—CORNISH BOILER.

A. Into types having from five large flues to ten as shown in Fig. 2.

Q. The natural development of the ten flue boiler was what?

A. The "multitubular" type, having a great many tubes or flues comparatively small diameter in place of a smaller number of large flues. (Figs. 3 and 4.)

Q. How was this developed?

A. By passing the hot gases of combustion through a lengthwise flue, passing through the water the entire length of the boiler.

Q. What did this develop into?

A. The "Cornish" boiler, in which

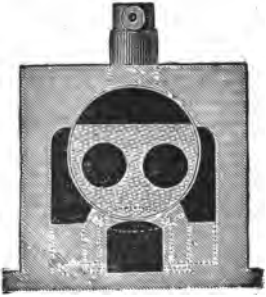


FIG. 7.—LANCASHIRE BOILER.

the fire was put in this large flue.

Q. What is one special advantage of the Cornish boiler? (Fig. 5.)

A. It may be set up without brick work if necessary.

Q. In the Cornish boiler, which expands the most, the shell or the flue?

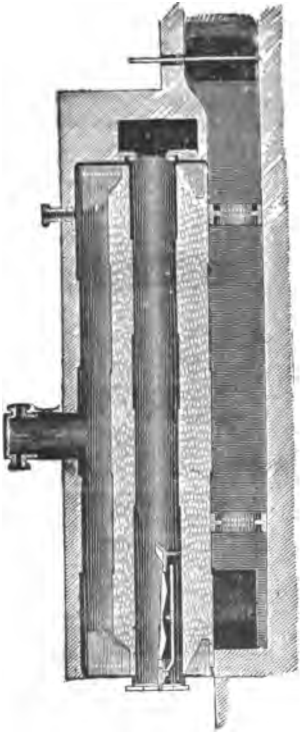


FIG. 8.—LANCASHIRE BOILER IN LENGTHWISE SECTION.

A. The flue.

Q. How is this remedied?

A. By having in the circumferential joints, rings of V section; or by having flues corrugated circumferentially.

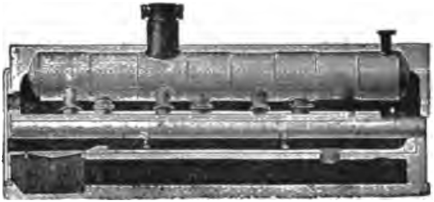


FIG. 9.—ELEPHANT BOILER.

FIG. 10.

Q. What did the Cornish develop and enter into?

A. Into the "Lancashire," having two flues in the side, because on large sizes the single internal flue was too weak. (Fig. 7.)

Q. What is the "breeches flue" boiler?

A. It has two furnace tubes combined with one long one behind the bridge.

Q. What objection to this?

A. Difficult to make and to keep tight in the crotch.

Q. What is the "Galloway" boiler?

A. There is an internally fired elliptical flue, strengthened by conical cross-tubes acting as stays.*

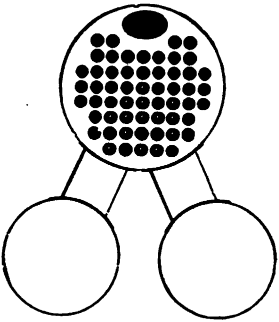


FIG. 11.—FRENCH TYPE HORIZONTAL BOILER.

Q. What is the "French" or "elephant" boiler?

A. There are two horizontal cylinders below a third and larger, with which they are connected by water tubes.

*See detailed description pages 50 to 53 inclusive.

Sometimes there are three below and one above.

Q. What is the Fairbairn type?

A. It is shown in Figs. 12 and 13, and is practically an internally fired

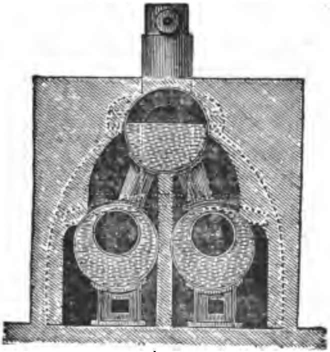


FIG. 12.—THE FAIRBAIRN BOILER.

"French" or "elephant" boiler, having two water boilers proper, below, each with one large flue containing the furnace. These connect with a common drum above.

Q. What is the Rastrick boiler?

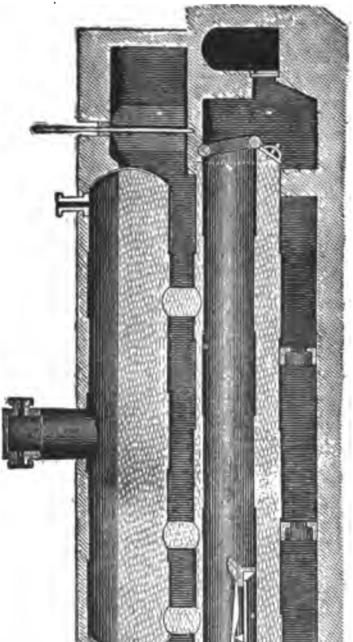


FIG. 13.—THE FAIRBAIRN BOILER.

A. A vertical cylinder with one central lengthwise flue, communicating with two or more horizontal flues through which the gases from the furnaces pass on their way through the central flue to the stack.

Q. What is a coil boiler?

A. One in which there is a continuous coil in one end of which the feed is pumped or otherwise introduced, the circulation thus being positive, and the quantity of water in the boiler at any one time very slight.

Q. Are coil boilers now in general use?

A. No, not as yet, although they are coming more and more into use for launches and other small boilers afloat; also for steam fire engine work; and there seems to be a tendency that way on small sizes and quick work; also for amateur service.

Q. What are the advantages of the coil boiler?

A. Compactness, safety, capacity, and early steaming power; the fact that it will not let sediment or scale collect in the tubes.

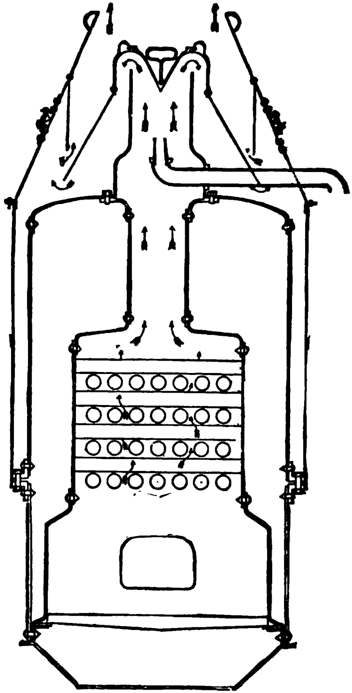


FIG. 14.—WESTINGHOUSE CROSS-TUBE BOILER.

Q. What are its disadvantages?

A. Liability to be quickly burned out if the feed stops for even a very short time, or to have the pressure rise very quickly if the call for steam is lessened or stopped.

Q. Describe and show a cross-tube boiler?

A. There are two parts of the shell; the lower forming the fire box and containing water tubes, and the upper one a shell surrounding the tubes and composing the water and steam space. The two are joined by strongly bolted rings. in connection with the vertical smoke tube at the top, and can be taken apart to clean the boiler or repair the tubes. The circulation is across the combustion chamber, through the horizontal water tubes, and is determined in one direction by a little cast iron hood at one end of each tube. Sparks are deadened and held by deflecting hoods. See Fig. 14.

Q. What is the Latta boiler?

A. There is an inner and an outer shell with an annular space C between; and in the central fire box area, over the grate, is a compound coil consisting of

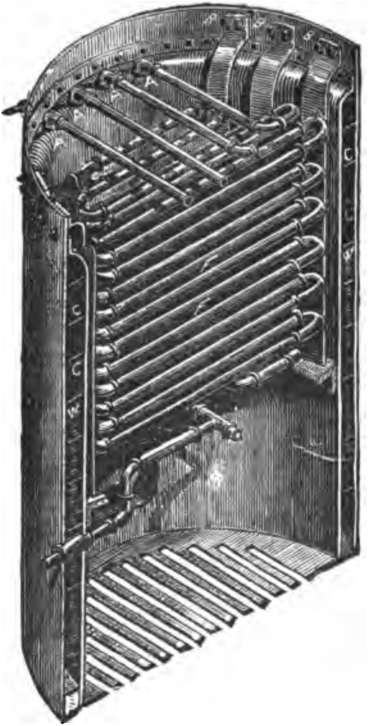


FIG. 15.—LATTA COIL BOILER IN VERTICAL SECTION

four sets of pipes fed by the pump from the bottom and in which the steam is generated. These coils are formed of straight lengths and return bends; they

FIG. 16.—TOP VIEW, LATTA BOILER.

are hung to the straps B, and discharge into the steam room at A.

Q. What is a sectional boiler?

A. One in which the principal portions are composed of a large number

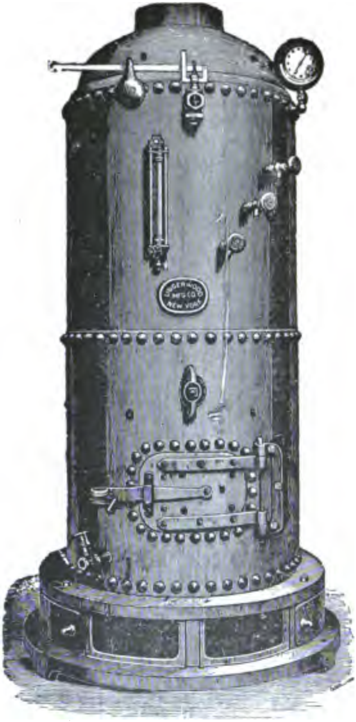


FIG. 17.—UPRIGHT TUBULAR BOILER (LIDGERWOOD.)

of similar pieces (as tubes or hollow spheres) of small diameter, joined into sections and these again united with a common steam and water drum.

FIG. 18.—BOTTOM VIEW, LATTA BOILER.

Q. What is a tubular boiler?

A. One having a number of comparatively small tubes or flues for the passage of the gases of combustion; these tubes or flues being surrounded by water.

Q. What is a tubulous boiler?

A. One having a number of comparatively small tubes containing water and surrounded by the gases of combustion.

Q. What is a flue boiler?

A. One in which the products of combustion pass through comparatively large tubes surrounded with water.

Q. What type of boiler is the most common?

A. The tubular.

Q. What is a drop flue boiler?

A. One in which the flames or products of combustion pass up and over a bridge, along tubes to the back of the boiler; then down, through tubes to the front of the boiler; then again through still lower ranks of tubes to the front, and then to the up take.

Q. What is the disadvantage of the drop flue type?

A. They are apt to crack and get leaky, by reason of the unequal expansion and contraction of the sheets where the various ranks of flues enter them.

Q. Are drop flue boilers generally internally or externally fired?

A. Internally.

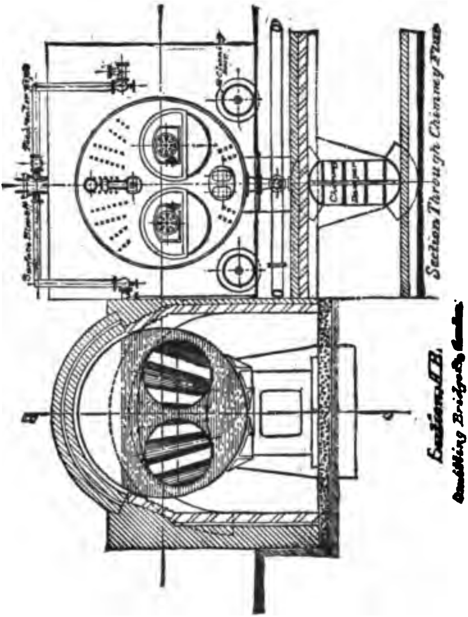


FIG. 19.—GALLOWAY BOILER AND SETTING.

Q. Which takes up less space, a tubular or a doubled decked boiler?

A. The double deck takes up less floor space.

Q. What is the objection to a vertical boiler having a convex bottom directly over the fire?

A. The pot bottom tends to collect deposit right over the hottest part of the fire.

Q. Show how horizontal flues are choked up by ashes, and how horizontal water tubes are covered with the same?

A. The water tube is covered over less of its surface than the flue is, and besides is covered over that portion which

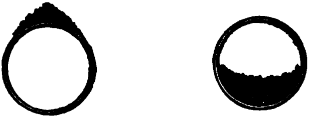


FIG. 20.—FLUES AND WATER TUBES.

has the least value for heating, while the flue is covered over its best portion.

Q. Describe the Galloway boiler.

A. The boiler presents a plain cylin-

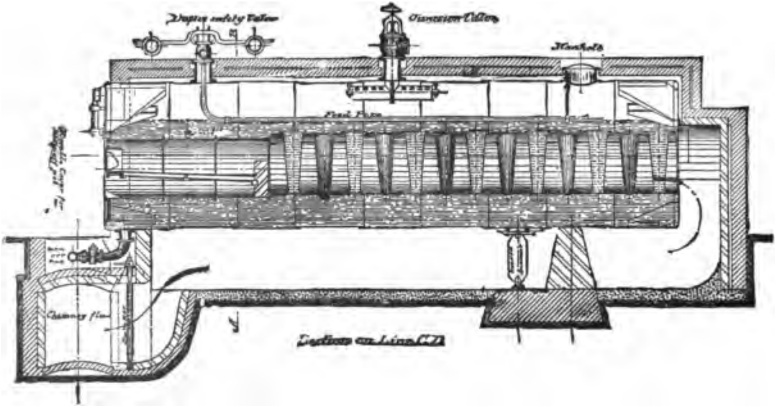


FIG. 21.—GALLOWAY BOILER AND SETTING.

drical shell, within which are placed two cylindrical furnaces, which unite into one back flue, oval in form; the top and bottom of this flue are curves struck from a common centre located below the flue; its sides are semi-circular excepting where bulged pockets or bafflers are formed, which assist in staying and strengthning the flue.

The Galloway tubes are conical in shape, both ends being flanged; the larger end is riveted to the top plate and the smaller end to the bottom plate of the oval flue. The tubes are arranged radial to the same centre used for the top and bottom plates of the oval flue, and are therefore of same length and interchangeable. They tend to support the bottom and top sheets of this flue against collapse.

The peculiar form of the oval flue, together with the arrangement of the conical tubes, is the distinctive feature of the Galloway boiler.

Q. Describe the "downward tubular" boiler?

A. In the "Miles" boiler there are two shells, one above the other, the up-

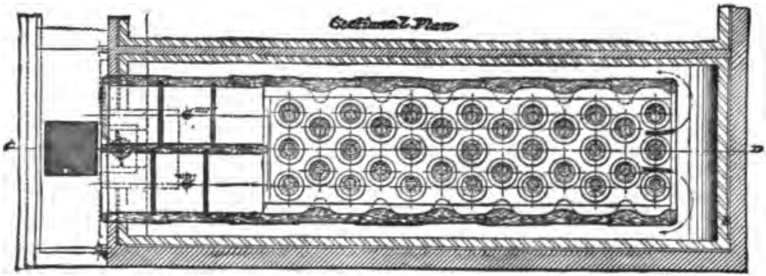


FIG. 22.—GALLOWAY BOILER AND SETTING.

per being horizontal and the lower one inclined about 20 degrees or so from

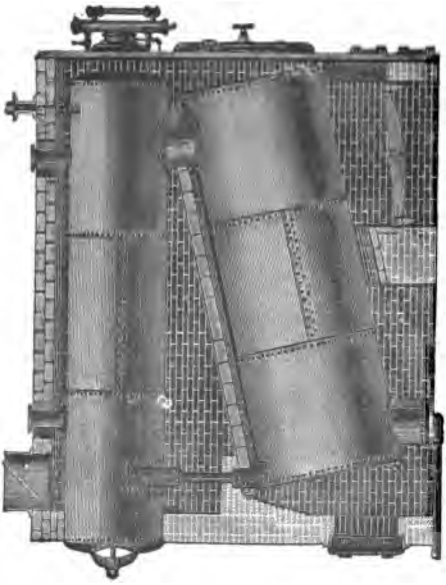


FIG. 23.—MILES' DOWNWARD TUBULAR BOILER.

the horizontal, the rear end being the lower and having a mud drum which

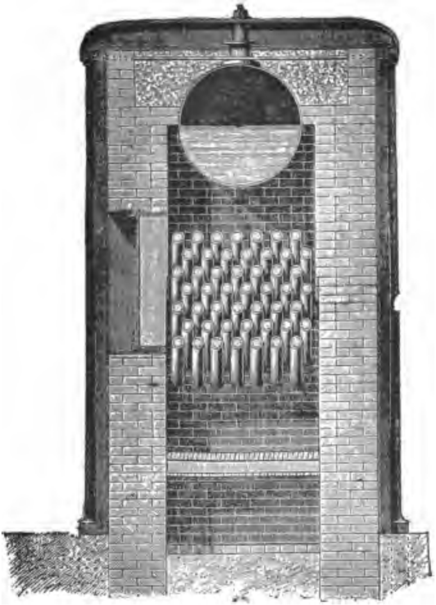


FIG. 24.—END VIEW, BABCOCK & WILCOX BOILER.

also supports the back end. The lower shell is tubular. The two are united in

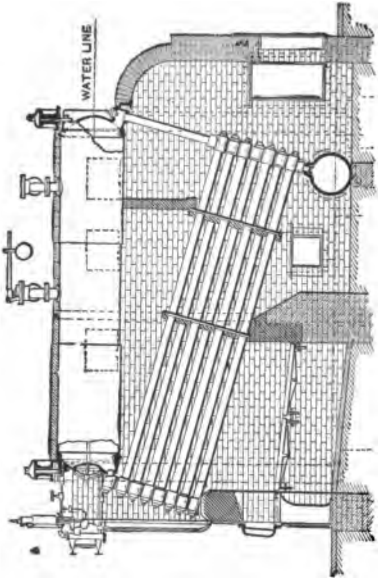


FIG. 25.—BABCOCK & WILCOX TUBULOUS SECTIONAL BOILER.

front by a large neck, and at the rear by a number of vertical tubes. The gases of combustion pass backwards

and slightly downwards under the lower shell, then upward and forward through

FIG. 26.—BABCOCK & WILCOX BOILER SETTING.

its tubes (a suitable apron wall preventing them from going up the stack more

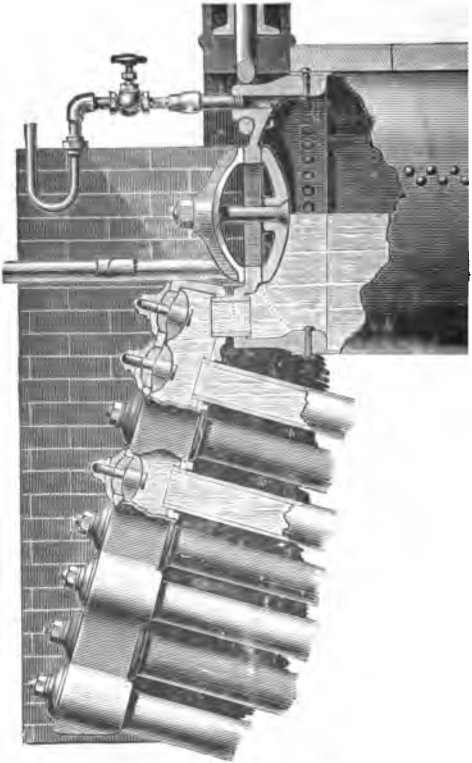


FIG. 27.—BABCOCK & WILCOX BOILER.

directly, then around and under the upper shell or drum, to the stack.

Q. What is the "Harrison" boiler?

A. It consists of a number of hollow spheres of Bessemer steel, each eight

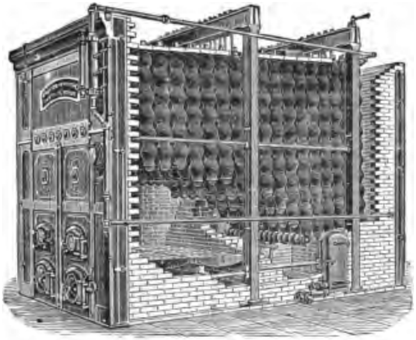


FIG. 28.—HARRISON BOILER AND SETTING.

inches in diameter and five sixteenths inches thick, connected by curved necks three and one-quarter inches in diameter. They are cast in sections of two or of four "units" or spheres, with opposite lateral openings to each sphere.

These units have ground rabbeted faces and are made into slabs by heavy through bolts, requiring no packing at the joints. A given number of slabs are suspended in an inclined position, side by side, from an iron frame work, and are joined at the top and bottom by suitable connections, forming steam and water couplings or passages. The whole structure is then surrounded by brickwork, forming the fire place and combustion chamber.

Q. What is the construction of the Shapley vertical portable boiler?

A. It is practically a two story boiler, the upper section projecting downward a little distance into the lower. In the lower section there is a tall, truncated, conical fire box having around its upper end short horizontal flues, extending outward through the downward projection of the upper shell, into a smoke tain ground the top of the lower section. The gases of combustion pass through these horizontal tubes into the smoke ring, then down through long vertical flues which pass through the annular leg of the lower shell, entering and

FIG. 29.—SHAPLEY VERTICAL PORTABLE BOILER.

annular water base or smoke passage in the base. The upper section has in it water to a sufficient height to cover the flat crown sheet of the fire box. This crown sheet and the head of the upper shell are stayed together.

Q. How do you get at the horizontal and vertical flues?

A. The smoke ring into which they open has its outer wall made of removable sections.

Q. Sketch and describe a vertical tubular portable boiler?

A. That of the N. Y. Safety Steam Power Co. has an upper crown sheet which extends across the full diameter of the shell; the lower sheet covering only the fire box. The two are connected by vertical tubes discharging into a conical smoke box. Baffle plates tend to diminish the tendency to lifting, caused by the escape of the steam from the surface of the water.

Q. Sketch and describe the Baxter two-horse boiler?

A. The combustion chamber has an open top and is surrounded by an annular passage between it and the inner

shell. The gases of combustion pass downwards through this annular passage and passing below the leg turn outward and then ascend in an annular passage

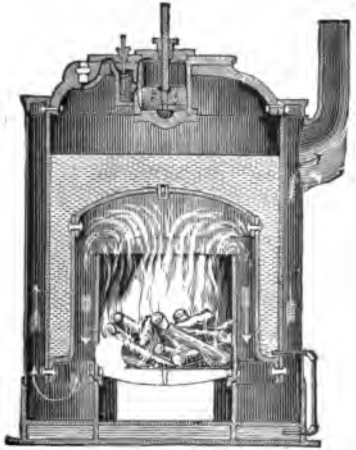


FIG. 30.—BAXTER 2 H. P. BOILER.

between the outer boiler shell and the smoke jacket. Thus there is flame under the crown-sheet and hot gases of combustion both within and without the

water-leg. The feed is slightly heated in a flat "safety chamber" below the ash box.

Q. Describe a boiler having both drop tubes and vertical flues?

A. The "Silsby" boiler has an inner and an outer shell, with water leg between; the vertical flues D extend from the upper head to the crown sheet, from which depend concentric circles of drop flues C; those of the outer circles being the longest. In each of these water tubes, which are closed at their lower ends, there is an inner "circulation tube" down which the water passes, the lower ends of these tubes being cut away to allow it to pass up between the two concentric tubes. Thus the steam is generated in the drop tubes C, from water which has been heated by the crown sheet and smoke flues D; and the steam is further heated by the smoke flues and by the smoke box above it The drop is of course urged, when in service, by the exhaust from the (rotary) engine.

Q. What is the Clapp & Jones new style of steam fire engine boiler?

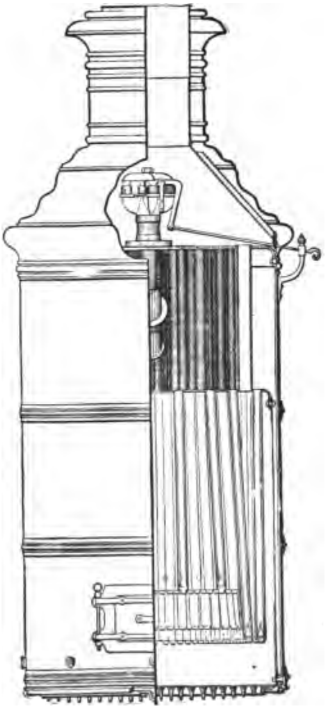


FIG. 31.—SILSBY STEAM FIRE ENGINE BOILER AND DROP TUBE.

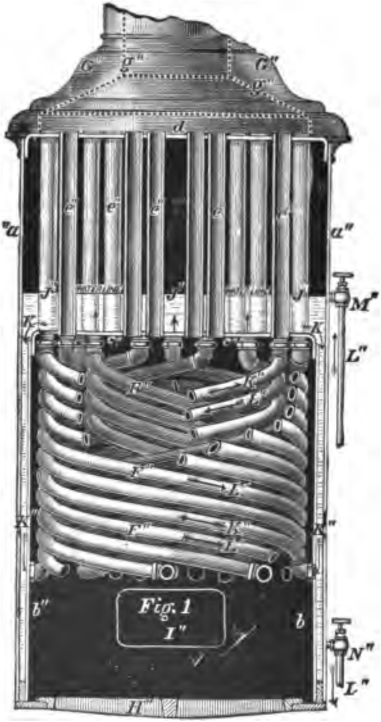


Fig. 32 —CLAPP & JONES' NEW STEAM FIRE ENGINE BOILER.

A. Clapp & Jones' new stoam fire engine boilers have about 4″ of their lower ends in the water, the rest being surrounded by steam.

The special feature is the substitution for the old straight drop tubes with low-

FIG. 33.—CLAPP & JONES' BOILER.

er end closed and with circulation plates therein, of sectional coil tubes, extending from the water leg to the crown sheet, there being six of these in each of three concentric circles in the size shown. Each coil is connected with the crown sheet (also with the fire-box sheet)

by a right-hand screw joint on an angle elbow requiring no fibrous nor elastic packing, and each coil section is removable.

G is the dome or covering, *g* the smoke bonnet and pipes for concentrating the escaping products of combustion; *H*, grate bars; *I*, fire door; *JJ*, water line.

When steaming, the circulation is from the water leg up through the spiral drop tubes, as shown by the arrows *K*. *M* shows the pipe from the heater, and its valve, which is a combined stop and check; the arrows *L* the direction of circulation when attached to the heater; *N* the valve and pipe from boiler to heater, the valve being a trip which is automatic or hand-managed as desired.

Q. What is a stationary boiler?

A. Properly, any boiler that is not moved from place to place; but in practice, a permanently set boiler, not adapted in form for use in locomotives, vessels, or portable engines

Q. What is meant by a portable boiler?

A. A portable boiler is properly any

one which can be taken from place to place while entire; but in America the term generally refers to a modification

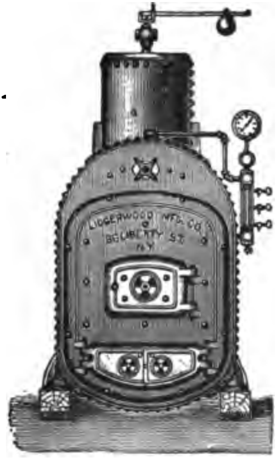


FIG. 34.—PORTABLE WATER-BOTTOM LOCOMOTIVE BOILER. (Lidgerwood.)

of the locomotive type, having generally a straight top and a water bottom.

Q. As regards their uses, can you name some kinds?

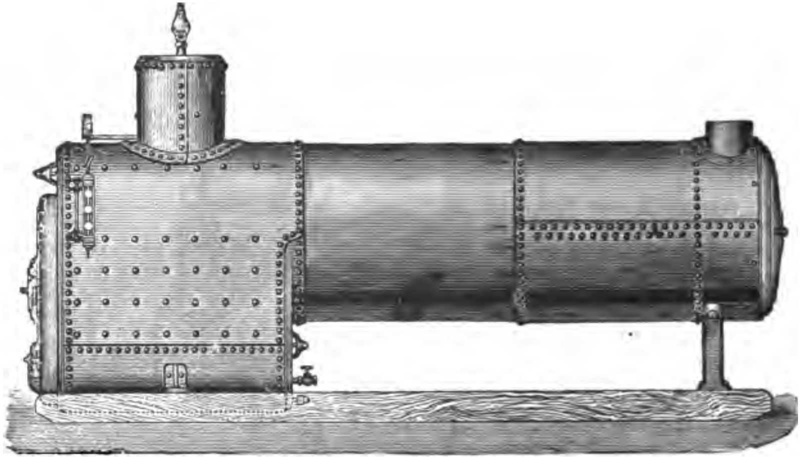


FIG. 35.—PORTABLE WATER-BOTTOM LOCOMOTIVE BOILER. (Lidgerwood.)

A. Stationary, portable, marine, locomotives, agricultural, fire engines, etc.

Q. What is a marine boiler?

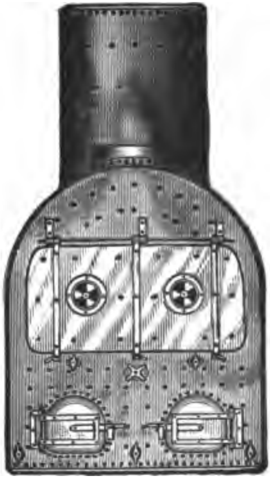
FIG. 36.—HORIZONTAL RETURN TUBULAR. Stationary, with dome and brackets. (Lidgerwood.)

A. One specially adapted for use on board ship.

Q. Describe the marine boiler?

A. It has at one end a fire box sur-

rounded with water, and from this flues extend to a combustion chamber or "back connection" at the other end;



FRONT VIEW, DOMED MARINE BOILER.
(Lidgerwood.)

this being surrounded by water spaces also, and running up nearly to the water line. From the front part of this

chamber, above the flues, there extend horizontal return tubes to the front of the shell. The gases having passed for-

SIDE VIEW, DOMED MARINE BOILER.
(Lidgerwood.)

ward through the flues into the chamber at the back, return through the small flues to the front and enter the uptake.

Q. What are the good points of this kind of boiler?

A. There being water all around the fire (even the bottom of the fire box being a water space), there is a maximum amount of heating surface, and a minimum amount of danger from fire in the adjoining woodwork; the boiler is compact for a given capacity, and is self contained.

Q. What are the disadvantages?

A. It must be large in order to be entered for inspection and repairs; and is expensive in first cost.

Q. What is a necessity in making marine boilers?

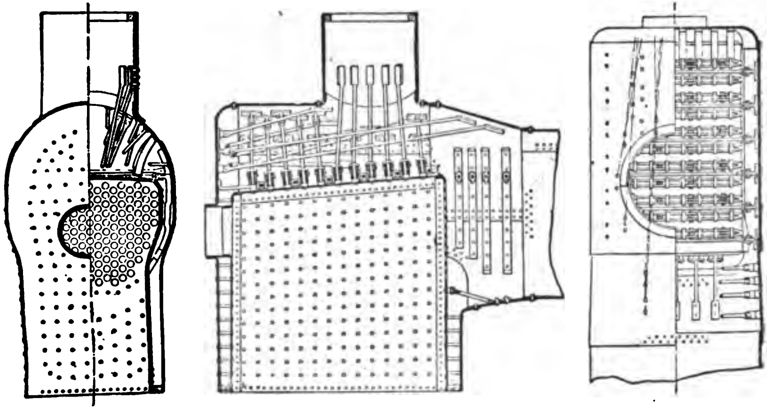
A. That the flame must be within the shell.

Q. How large are marine boilers made?

A. Up to 10 feet and more in diameter (for low pressure engines using only 25 pounds steam pressure).

Q. What is meant by a locomotive boiler?

A. A locomotive boiler is generally understood, in this country, to have an outside fire-box with flat sides and a round top, and open bottom; a thin



LOCOMOTIVE BOILER.

water space between that and the inside fire-box, which latter has a flat or nearly flat crown sheet. The fire-box is connected with a horizontal cylindrical barrel, at top parallel or nearly so with that of the outer fire-box. There is often a tapered waist piece between the fire-box and the cylindrical barrel. The barrel is supplied with a great number of long tubes of small diameter. There is sometimes an extension front to catch the sparks and cinders lifted from the grate by the great force of the blast and swept through the tubes without being consumed. The crown sheet is stayed by cross-bars or by sling stays; the water legs or spaces between inner and outer fire-boxes are stayed with short straight stays about four inches apart. There is generally a dome over the fire-box, or on the cylinder part just in front of the fire-box. The draft is forced by the exhaust of the engine.

Q. What definition of locomotive boiler can you give that will cover the type whether applied to stationary, locomotive or marine service?

A. One having a horizontal cylindri-

cal shell or waist, connected at one end to a casting surrounding an internal fire-box, and a series of fire tubes passing from end to end of the shell and serving to conduct the products of combustion from the fire-box at the farther end of the shell.

Q. Name some of the advantages of the locomotive boiler?

A. It is self-contained; can be set without brick work if necessary; has an immense amount of heating surface for a given amount of grate, the fire is entirely surrounded by water; there is more space between the grate bars and the crown sheet than almost in any other.

Q. What are the distinctive features of the Wootten locomotive boiler?

A. A comparatively shallow fire-box which is extended laterally to any limit desired, within the width prescribed by that of the roadway, and which is located usually somewhat above or only to a slight degree below the lower line of the waist; a combustion chamber interposed between the fire-box and the flue sheet, and a fire bridge extending across the fire-box end of the combustion

chamber for a portion of its height sufficient to permit a fire of proper thickness to be carried on the grate without allowing fuel to enter the combustion chamber or tubes; the fire bridge obviating the necessity which would otherwise exist, of placing the bottom of the waist at a materially higher level than the surface of the grate. The crown sheet is stayed directly to the shell by bolts, in the manner of the side sheets; crown bars not being employed.

Q. What are the various types of boilers as regards their construction?

A. The same question practically occurs under another head; there may be mentioned plain cylinder, flue, internal fired flue, tubular, return tubular, tubulous, sectional, drop tube, coil, "porcupine," etc.

Q. What do you mean by a fire-box boiler?

A. One in which the fire is burned in a metal fire-box, not in a brick set furnace.

Q. What classes of boilers are included in the fire-box type?

A. All locomotive, nearly all marine, and many stationary boilers.

Q. What is one great disadvantage of sectional boilers?

A. That they have but small quantity of water in them and hence are liable to fluctations of water level.

Q. What are the disadvantages of the double deck boiler?

A. It is very heavy, costs high, and is difficult to clean or repair.

ELEMENTS OF STRENGTH.

Q. On what does the strength of a boiler depend?

A. On the form, material, dimensions, joints, stays, domes, nozzles, man-holes, hand holes, etc.

Q. What is the factor of safety?

A. The proportion between the load recommended or used and the possible load.

Q. What is the usual factor of safety of boilers in America?

A. Six.

STRENGTH OF FLAT,
CYLINDRICAL AND SPHERICAL SURFACES.

Q. What figure in construction is the stiffest?

A. The triangle; it cannot be de-

formed without bending, or altering the length of one or more sides.

Q. What two properties does the sphere alone possess?

A. It is the best of all forms for resisting internal pressure, and it contains the greatest volume for a given surface.

Q. By what should we measure the force tending to burst a hollow sphere?

A. By the area of the circular cross section through its centre, and not by that of its hemisperical surface.

Q. What is the advantage of a spherical boiler?

A. Simplicity; strength for a given weight of material; it expands easily on the application of heat to one portion of the surface, and does not readily cause leaks or fractures of adjacent parts.

Q. What are the disadvantages?

A. Expense of making from wrought iron or steel; small amount of heating surface compares with its volume.

Q. What is the advantage of having spherical boiler heads?

A. They require no bracing.

Q. What is the most usual form of boiler?

A. Cylindrical.

Q. What are the advantages of the cylindrical type?

A. Simplicity, cheapness of construction, inspection, and repair; wide range and different means of making, arranging and setting.

Q. By what is the force tending to rupture a cylindrical boiler lengthwise represented?

A. By the product of the diameter by the pressure on each unit of the surface.

Q. How is the force tending to rupture a cylindrical boiler lengthwise, calculated?

A. By multiplying the diameter by the pressure on each unit of the surface and by the length of the cylinder.

Q. What influence has length on the strength of a boiler to resist bursting?

A. None.

Q. What influence has length on the general strength of a cylindrical boiler?

A. The longer the boiler the greater the weakness caused by expansion and contraction in its setting.

Q. What is the tendency of the steam

pressure in a cylindrical boiler as regards its cross section?

A. To make it truly circular if not already so; to keep it truly circular if already so.

Q. Under what circumstances may the steam pressure tend to make a boiler of circular cross section elliptical or oval in places?

A. Where one ring of sheets or one section of length is weakened by a dome-hole or man hole, and not suitably re-inforced nor stayed.

Q In a wrought iron shell, can perfect circularity of cross section be obtained with lap-riveted seams?

A. No.

Q. How then?

A. By butt-riveting with a welt, or by welding the seams.

Q. What is the principal cause of the weakness caused by a lap-riveted seam?

A. The oblique strain caused on the plates and rivets.

Q. What is the tendency, under pressure, of a cylindrical shell having flat ends, and why?

A. To get barrel-shaped; because the

flat ends stay those portions of the convex shell nearest them.

Q. Where is a boiler of "oval" or elliptical cross section most likely to change its form?

A. At mid length, on account of the support given by ends being least there.

Q. Is there any rule for the strength of boilers of elliptical section?

A. No; because with every change of shape the resistance varies.

Q. What is the amount of force tending to burst a cylindrical boiler in a plane perpendicular to its axis (that is, to pull it apart endwise, or tear it apart crosswise)?

A. The amount of pressure on the two ends, represented by the cross area of the cylinder multiplied by the pressure per square unit of surface, that is P representing the square unit of surface, and D the diameter in corresponding lineal units, to P times D^2 times 0.7854.

That is, if the boiler is 60 inches in diameter and has 100 lbs. per square inch upon it, the pressure tending to burst it by pulling it apart endwise would be

$$100 \times 60 \times 60 \times 0.7854 = 282{,}744 \text{ lbs.}$$

Q. By what should we measure the force tending to burst a cylindrical shell lengthwise?

A. By the area of its lengthwise section, and not by that of its semi-cylindrical convex surface.

Q. What measures the resistance of a cylindrical boiler to the force tending to pull it apart endwise?

A. The tenacity of the material and the amount brought into play to resist the pressure—that is, the whole circular (or rather annular) cross section of the boiler and the whole tensile strength of the material, under ordinary circumstances.

Q. With the same internal pressure, diameter, and thickness of shell, which way is a cylindrical boiler the stronger, lengthwise or crosswise?

A. It is twice as strong crosswise as lengthwise.

Q. Then is a cylindrical boiler more liable to burst from lengthwise than from crosswise strains?

A. No; there are other influences at work modifying this rule.

Q. In what does material strained in

a boiler differ from that strained in a testing machine?

A. It is strained both lengthwise and crosswise at once in the boiler.

Q. Has this any influence upon the strength of the material?

A. Napier has shown that it has not.

Q. What might be said of hemispherical ends for cylindrical boilers and having the same thickness as the sides?

A. They would be unnecessarily strong.

Q. How may the ends of a cylindrical boiler be brought to the same strength as the sides?

A. By cambering the ends to a radius equal to the diameter of the shell, so that they will be parts of a a sphere having a diameter double that of the barrel.

Q. What is the effect of diminishing the camber, or amount of dish, of convex boiler ends?

A. The tensile strength is increased, and the resistance to bulging reduced, and they will be of more use in strengthning the cylindrical part.

Q. Could the unstayed flat end of a

cylindrical boiler be readily given only equal thickness with the convex shell?

A. Not without giving it monstrous thickness. For instance, a single riveted boiler, 36 inches in diameter and $\frac{3}{8}$ inches thick, would require a solid end-plate 2 inches thick to have equal strength in the ends and in the sides.

Q. Please give me the rule for safe working pressure of any cylindrical boiler shell?

A. Divide the thickness of the boiler plate in inches by the diameter of the boiler in inches, and multiply by the proper constant number quoted below:

Steel double	riveted,	18,000	down	to	10,000
" single	"	14,500	"	"	7,500
Iron double	"	15,500	"	"	7,600
" single	"	12,500	"	"	7,000

Thus double riveted shell 56″ diameter, $\frac{1}{2}$″ thick; then safe working pressure is—

$$\frac{0.5}{56} \text{ times } 15{,}500 = 138 \text{ lbs.}$$

Q. Theoretically speaking, at what steam pressure would a boiler of the following dimensions burst: 9 feet long,

90 inches in circumference, $\frac{1}{4}$ inch thick, single riveted, charcoal iron; boiler heads well braced; containing sixty 2-inch flues?

A. The following is a standard formula for calculating the working pressure of steam in a boiler, supposing the working pressure to be one-eighth of the ultimate strength or theoretical bursting pressure: Divide the thickness of the boiler-plate in inches by the diameter of the shell in inches, and (for a single riveted wrought-iron shell) multiply the quotient by 7,600; the product will be the working pressure in pounds per square inch. In the case just put, therefore: divide 0.25 (the thickness of the plate in inches) by 30 (the approximate diameter, in inches) and the quotient is $0.0083\frac{1}{3}$. Multiply this quotient by 7,600, and the product is $63\frac{1}{3}$, which would be the working pressure; and if this is one eighth the ultimate strength, the latter would be $506\frac{2}{3}$ pounds per square inch.

Q. Which is the stronger, a cast iron head which is arched inward, or one which is arched outward?

A. One in which the arch is turned in.

Q. What is the objection to turning a cast iron head in?

A. That there is an acute angular space left between the head and the shell, and this is liable to retain deposit.

Q. In resisting external pressure, how may a cylinder or a tube be considered?

A. As an arch.

Q. What is the tendency of any external pressure on a tube or flue?

A. To aggravate any local flattening that may exist, or to flatten it where weakest.

Q. In a cylinder subjected to external pressure, is its strength affected by its length?

A. Yes.

Q. In what are internal and external pressure diametrically opposite in their effects on a cylindrical boiler?

A. Internal pressure tends to rectify any departure from circularity of cross section; external pressure tends to increase any such departure.

Q. What rule is generally given for the strength of cylindrical tubes subjected to external pressure?

A. Fairbairn's. Letting P represent the collapsing pressure per square inch, K the thickness of the tube in inches, L its length in feet, and D its diameter in inches, we have as a formula

$$P = \frac{33.61 \times 100K^{2.19}}{LD}$$

Log P = 1.5265 plus 2.19 log 100K minus log LD.

A more common rule is that the collapsing pressure per square inch equals 33.61 times the square of 100 times the thickness in inches, divided by the product of the length in feet by the diameter in inches. Thus, a tube 12 feet long, 3 inch external diameter, $\frac{1}{4}$ inch thick should stand

$$33.61 \times \frac{100 \times 100 \times 1\text{-}16}{12 \times 3} =$$

$$33.61 \times \frac{625}{36} = 33.61 \times 1736 =$$

5§3.47 pounds per square inch.

Q. Will using the square instead of the 2.19th power in this formula give

a higher or a lower collapsing pressure?

A. Higher.

Q. Should lap joints be used for tubes under external pressure?

A. No; as they cause a deviation from circular cross section, and this tends to be increased by the external pressure.

Q. Which is the stronger arrangement of built up flues, under collapsing pressure, with the length of the sections short or long?

A. Short.

Q. Which is the stronger arrangement of built up flues, under collapsing pressure, with the lengthwise seams breaking joint or not?

A. Breaking joint.

Q. With what does the difficulty of maintaining the cylindrical form of tubes under external pressure increase?

A. With the diminution of the ratio between the diameter and thickness, but the influence of this ratio is very slight up to tubes having a diameter of 150 times the thickness.

Q. What is the thinnest plate which should be used in a boiler, and why?

A. One-fourth inch—on account of

the difficulty of calking the seams of thinner plates.

Q. What puts a limit to the thickness of plates?

A. The liability to burn on the outside, and the great contraction which a very hot rivet of the necessary length would have in cooling.

Q. What is the limit?

A. One inch, or perhaps much less.

Q. How does the collapsing pressure of flues or tubes vary?

A. Inversely as the length and diameter, and about as the square of the thickness.

Q. What should be the cross section of the main flue of an internally fired boiler?

A. Truly circular.

Q. What is the next best thing to a truly cylindrical form, for the main flue of an internally fired boiler?

A. A butt joint with a welt underneath.

Q. What are the disadvantages of this?

A It is impossible to calk the seam when in place, and the line of rivets

prevents the removal of ashes and dust; also if the joint leaks, there will be an accumulation of hard baked ashes and cinders its whole length, and if there is sulphur in the fuel it will cause external corrosion.

Q. What is the only cross section which tends to maintain its shape under steam pressure?

A. Circular.

Q. What tendency has either an elliptical or an oval section when under internal pressure?

A. To get circular.

Q. What tendency has a flat surface under internal pressure?

A. To become externally convex or bulged.

Q. How is this tendency resisted?

A. By "stays" or tension members, preferably connecting and holding together two flat surfaces which tend to separate from each other.

Q. Of what are stays made?

A. Of rods, tubes, and plates; the latter generally called "gussets." Crown sheets are in part stayed by the tubes therein.

Q. How are flat crown sheets stayed?

A. Usually by crown bars and bolts; sometimes, and preferably, by round screwed stays, riveted over or fitted with nuts.

Q. What special treatment do screwed steel stay-bolts require in working?

A. In hammering down a screwed steel stay-bolt with the thread left on, there is danger of foliation and causing the head to snap off. This may be obviated by turning the thread off the end.

Q. When longitudinal tie rods are used as stays, how are the L or T irons securing them arranged?

A. Horizontally.

Q. How are gusset stays usually arranged?

A. In planes radiating from the axis of the boiler.

Q. What is the best arrangement for T iron stiffening ribs?

A. That depends on the design of the boiler.

Q. If the form of a boiler head was hemispherical, would it stand a greater pressure than the other sheets of the

boiler, all being made of the same material and the same thickness?

A. A spherical head would not need to be braced, but it would not be any stronger than the other parts of the boiler, because the shell would be as strong as that part of the head which was riveted to the shell.

Q. What is the strain allowable by the United States Steamboat Inspection Regulations on a boiler brace (or stay) of one square inch of cross section?

A. Six thousand (6000) lbs.

Q. What "factor of safety" does this allow for?

A. From eight to ten, according to the actual breaking strength of the stay.

Q. What is generally the weakest point of a tubular boiler—the flue sheet or the crown sheet?

A. In boilers which were correctly constructed one part would be as strong as another, but the crown sheet being exposed to the greater heat, would require more care and attention.

Q. Why are not sheets thicker than one-half inch much used in making boilers?

A. Because they are more difficult to rivet.

Q. Is any metal thinner than 3-16

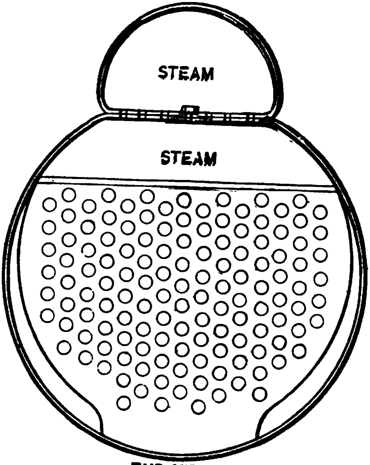


FIG. 37.—WEAK CONSTRUCTION.

inch used for boiler making?

A. It cannot be calked well if thinner than that, hence is not used.

Q. What would be the tendency under steam in a boiler constructed as here shown?

A. The tendency of the main shell would be to assume a circular cross section; so would be that of the upper shell; hence there would be a disposition to tear the shells apart, commencing at the outer edges of the flat lapped joint.

FLANGING.

Q. How should iron or steel plates be managed?

A. With wooden mauls over a cast-iron former and with light blows distributed over large surfaces. Short bends should be avoided.

Q. In flanging steel, what precaution should be taken?

A. To heat a larger portion at a time than with iron.

Q. What is a good way of annealing steel boiler plates?

A. Immersion in fire ashes or sand while hot.

WELDED JOINTS.

Q. What are the advantages of welding joints?

A. Welding comes more nearly to the effects of a solid plate than riveting does, and needs no calking; besides welded seams may be re-rolled so as to make a perfectly cylindrical shell, which is impossible with ordinary lap joints.

Q. What is the main advantage of welded seams over riveted ones in external fire boilers?

A. There is no double thickness of plates in the fire.

RIVETED JOINTS.

Q. What is the strength of a single riveted joint as compared with the solid plate?

A. That depends on how the holes are made and the riveting is done; on the thickness of the plate, the opening, etc. It will run from 40 to 60 per cent. of that of the plate.

Q. How about riveted joints?

A. They run from 50 to 70 per cent. as strong as the solid plate.

RIVETING.

Q. How are rivets best fastened up?

A. Rivets are best fastened up by power; particularly where long in proportion to their diameter, and where holes are

punched with considerable flare. Steam, pneumatic, and hydraulic riveters are in use, and do good, tight, sightly work.

Q. Which is the stronger; chain riveting or zigzag riveting?

A. Chain riveting has been proved (by Mr. Boyd). to be 24 per cent. stronger than zigzag; from 16 to 19 per cent stronger than single riveting.

Q. Are steel rivets desirable to use?

A. Steel rivets have been but little used and in but slight favor, owing to their high tensile strength and low ductility.

Q. What precaution must be used with steel rivets?

A. They should be uniformly heated throughout; should never be heated above a bright cherry-red, and never heated in a thin fire nor in one having a forced blast.

Q. What precaution should be taken with riveted joints?

A. Not to get the holes too near the edge of the plate.

Q. What is the best rule for riveted joints?

A. To make the strength of the plate

just equal to the resistance of the rivet to shearing.

Q. Is there economy in double riveting, if so, why?

A. There is economy in double riveting, because it gives increased strength without corresponding increase in cost.

Q. What should be done to the edges of the plates before riveting together?

A. They should be planed or sheared to a bevel, of about 70 degrees.

Q. What is the objection to chipping seams after riveting?

A. It weakens the plate underneath by scoring with the chisel.

Q. What is the best form of punch for making rivet holes?

A. One having a gradually acting cutting edge so as not to consume power by cutting all around the periphery of the hole at once; this at the same time gives a neat shearing cut.

Q. What is the advantage of having butt-wielded lengthwise joints instead of single or double lap joints?

A. Does away with furrowing at seams.

Q. How can the mud ring of locomo-

tive boilers be made so that it will not leak?

A. By giving it two rows of rivets.

FIG. 38.—KENNEDY'S SPIRAL PUNCH.

Q. Which needs the most rows of rivets; lengthwise or circumferential seams?

A. The lengthwise seams.

Q. What care should be taken with regard to riveted seams?

A. They should not be placed where they will be exposed to the direct action of the fire, if it is possible to put them elsewhere.

TUBE CUTTING.

Q. Describe and sketch some one of the forms of tube cutters which are upon the market?

A. One consists of a cylinder having a slot through its entire length, also a transverse slot, which holds a tool. This cutting tool is forced up by a wedge into a tube and when the cylinder is revolved by means of a ratchet wrench, the tool cuts the tube. An adjustable guide gauges all the cuts a like distance from the tube sheet.

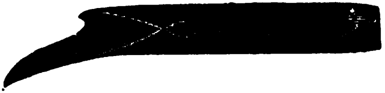


FIG. 39.—TUBE BEADING TOOL.

Q. How should tubes be made to hold well and be tight in the heads?

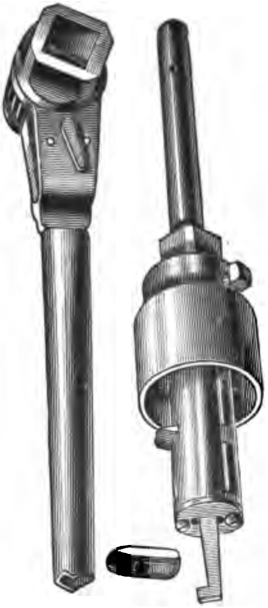


FIG. 40.—TUBE CUTTER.

A. By a roller expander.

Q Is "beading over" beneficial?

A. I think not; it destroys the material of the end.

FIGS. 41 AND 42.—ROLLER TUBE EXPANDERS.

Q. Describe and draw some one of the tube expanders upon the market?

A. One of them consists of 3 rolls, a

taper rod, and two discs held together by 2 studs; upon the inner faces of the

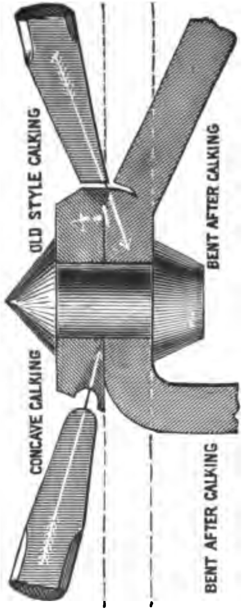


FIG. 43.

discs are 3 grooves radiating from the centre. The bearings on either end of

the rolls slide in the grooves and are guided thereby, and held in position. These rolls are forced outward by the taper rod, against the inner side of the tube, and by rotating the rod, the rolls also revolve, and these expand the tube. The machine is provided with an adjustable collar guide, which allows it to enter each tube only the desired distance.

CALKING.

Q. What is meant by calking in boiler making?

A. Upsetting the over-lapping edges of plates to make the joint steam tight.

Q. What kind of a nose should a calking tool have?

A. It should have a wide end, rounded off so as to leave a concave track.

Q. What is the objection to calking with a sharp edge tool?

A. It does not make a very tight steam joint, and it scores and weakens the under plate.

SETTING.

(Naturally, most of the matter which could go under the head of "Setting" is distributed under more appropriate head-

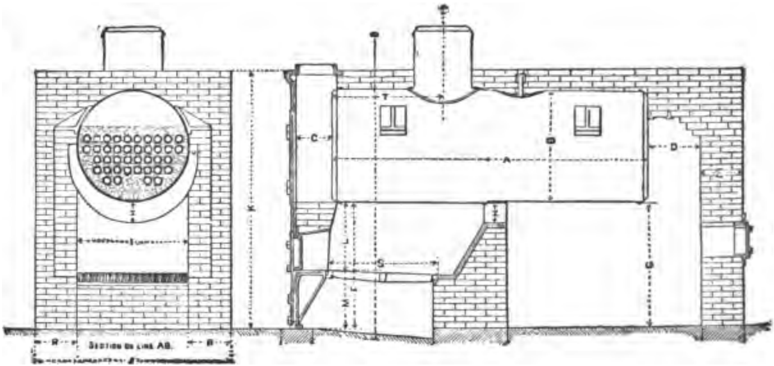


FIG. 44.—RETURN TUBULAR BOLER SETTING.

ings, as Grates, Bridges, Drums, Chimneys, Fire Doors, Dampers, Coverings, Combustion, Fuels, Hot Blast and Smoke Consumption, etc., which please see.)

Q. What is the most frequent cause of boilers being badly set?

A. They are left to ordinary masons or brick-layers to be set according to their ideas.

Q. Where should boilers never be placed?

A. In dark cellars or any other places where they cannot be properly seen and seen to, nor where the comfort and health of the fireman will be prejudiced.

Q. How would you lay a brick wall for a boiler setting?

A. First dig a trench following the outline of the foundation wall and from 18 to 24 inches wide, according to the weight of the boiler when full, then run in concrete about a foot thick, and tamp it down well. Then erect the brick wall.

Q. How would you prevent the side walls of this brick setting from spreading?

A. By binding them together with wrought iron ties passing through and

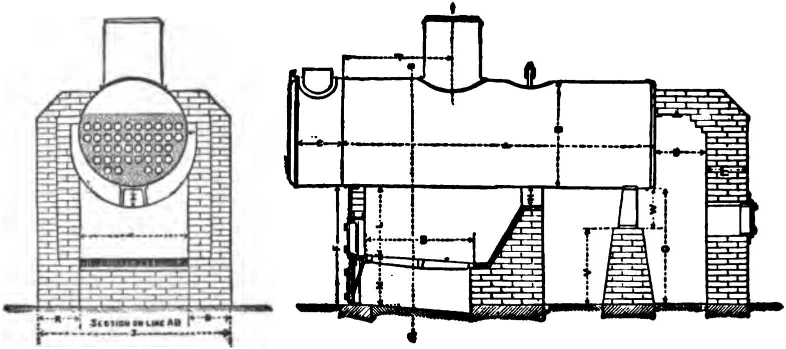


FIG. 45.—SETTING OF RETURN TUBULAR BOILER. (Erie City Iron Works.)

bearing upon, at each end of the ties, cast iron plates (buck-stays) to distribute the pressure.

Q. What mortar should be used in setting the brick work of a boiler?

A. Cement; *not lime*, as this tends to corrode the plates.

Q. Should flame be allowed to strike any portion of the shell above the water line?

A. No.

Q. In setting, should a boiler have much or little of its surface exposed to the heat?

A. All that is possible.

Q. What is the best way to equalize the heat upon the various portions of the boiler and yet not expose the shell to the direct action of the flame above the water line?

A. To carry the gases of combustion over the top of the boiler in a brick flue.

Q. Would not this cool down the steam? These gases would certainly not be as hot as they were when passing through the tubes.

A. They are hotter than the air of the boiler room would be.

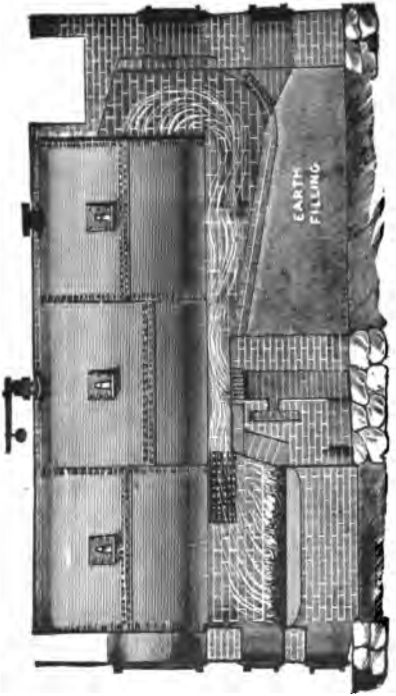


FIG. 46.—RETURN TUBULAR BOILER. (Jarvis setting.)

Q. How many ways are there of holding up a horizontal boiler?

A. Three principal ones: by wrought iron slings or hangers, by wrought iron or cast iron brackets, and by cast iron stands.

Q. What can be said about hanging long boilers by loops riveted to their tops and hung from cross beams?

A. It is a bad way, as the boilers are apt to lengthen unequally, top and bottom, and thus throw too much weight upon the middle hanger.

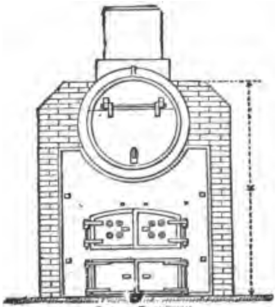
Q. What is the most permanent way of supporting boilers?

A. By riveting cast iron brackets to the ends and centre of the shell and setting these upon rollers, so that as the boiler expands and contracts there need be no resistance to it and no strain upon the brick setting.

Q. What objection is there against hanging boilers on brackets at the side?

A. Liability of the walls cracking and settling.

Q. In what case is it necessary to hang boilers by slings instead of supporting them upon brackets?



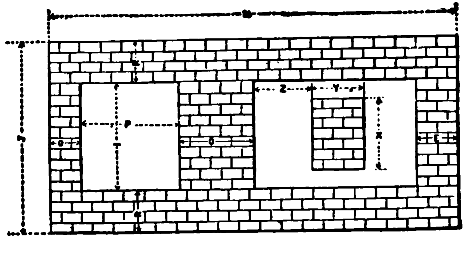


FIG. 47.—SETTING OF RETURN TUBULAR BOILER.

A. Where there are two or more in a battery without any division wall.

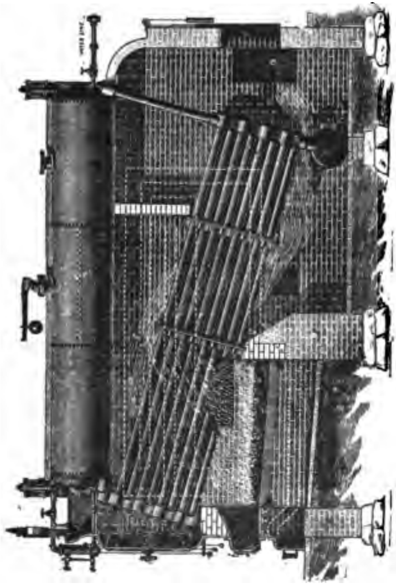


FIG. 48.—SECTIONAL WATER TUBE BOILER SET ON THE JARVIS FURNACE.—Dotted Lines Showing Air Passages.

Q. What do you think of central walls under boilers for supporting them?

A. They have some disadvantages; as for instance, they will tend to corrode the boiler if they touch it underneath; then again as the boiler expands and contracts, the brick wall will be worked loose and will tend to crumble at certain points, and thus bring too much pressure upon certain portions of the plates, which have to bear all the weight of the boiler and its contents.

Q. Why will not a boiler stand give trouble from expansion and contraction?

A. Because the back end of the boiler can be supported upon expansion plates; and the curve of the top of the boiler stand can be made exactly that of the bottom of the boiler shell, so as to distribute the weight.

Q. How is the front of a horizontal tubular boiler arranged?

A. There is generally a cast iron fire front, containing large doors to give access to the flues, and smaller ones for the furnace and the ash pit.

Q. How much of the boiler weight should this carry?

A. None.

Q. Does it carry no weight at all?

A Only the front end of the grate with its load of fuel.

Q. Does this cast iron front come flush with the front end of the boiler, or is it at some little distance from this?

A. It may be arranged either way. If it is flush, there is a projecting portion of wrought iron, called a breeching, to carry the gases of combustion.

Q. If the cast iron front is at some little distance from the front of the boiler shell, why do not the gases of combustion go right up in that space, instead of passing under the boiler and then through the tubes?

A. There is a brick arcn to prevent this.

Q. What is the disadvantage of having the cast iron front at some distance from the boiler front, instead of being flush with it?

A. The fireman has that much farther to throw his fuel, and can handle it less to advantage.

Q. What are the advantages?

A. The brick arch which forms the base of the flue gets hot and slightly heats the air which is admitted by the furnace door.

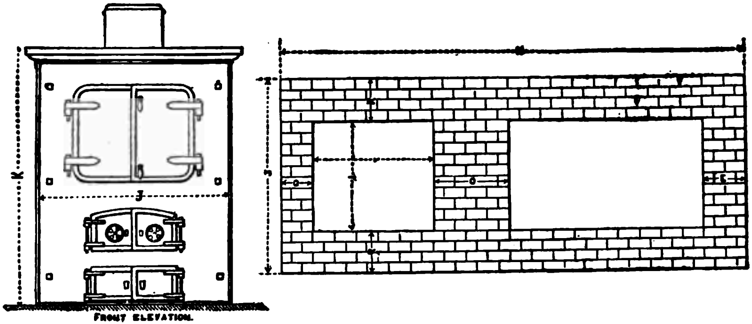


FIG. 49.—GROUND PLAN AND IRON FRONT.

Q. How is the cast iron front prevented from falling forward?

A. By anchor bolts from the side walls.

Q. What prevents this cast iron front from being cracked by the heat?

A. Sometimes no precaution is taken. Sometimes it is lined with fire brick.

Q. What is the "Dutch oven" setting?

A. There is a regular brick furnace built, with its back end flush with the front end of the boiler. Under the boiler there is a brick flue. The fuel is burned in the brick furnace, and the gases pass over the rear wall into the lower flue, then return through the tubes, then up through the breeching into the stack.

Q. What distance should there be between grate and shell for wood burning?

A. Twenty-four inches minimum; thirty will not hurt with large wood.

Q. Should grate bars be level or slanting; and if the latter, which way and how much?

A. Inclined downwards from the door say 3″ in 4 ft.

Q. Should the bridge wall be higher than the grate or not?

A. Yes; 18″ higher or more is usual.

Q. What is the principal use of the bridge wall?

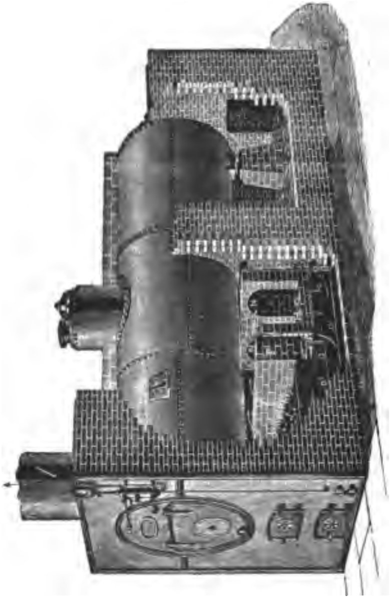


Fig. 50.—Lowe Boiler Setting.

A. To keep the fuel from being pushed back beyond the grate.

Q. No other use?

A. It is sometimes said to drive the flame or the gases up against the bottom of the shell; but as these gases are

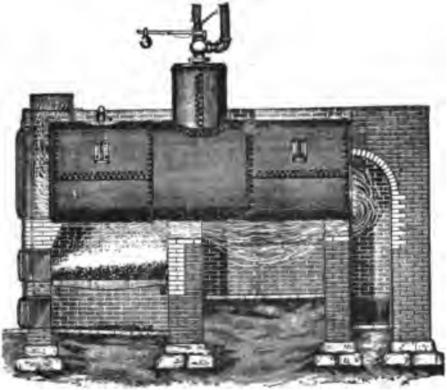


FIG. 51.—BRICK SET RETURN TUBE CYLINDRICAL BOILER. (LIDGERWOOD.)

hot and strongly tend to rise, the influence of the bridge wall in this particular would seem to be very slight with most settings.

Q. What is the disadvantage of build-

ing the bridge wall close to the boiler and leaving holes for the passage of gases?

A. If the coals are not kept pushed

FIG. 52.—PLAIN FRONT.

away from the front of the grate to let the air through, it will not work well

Q. How can this be got around?

A. By setting the grate so as to leave about 2½ inches between the front of

FIG. 52.—HENNESSY TRIPLE DRAFT BOILER. (Jarvis setting.)

the grate and the front of the furnace.

Q. What about the door in the back wall of the boiler setting?

A. It should be large enough to make

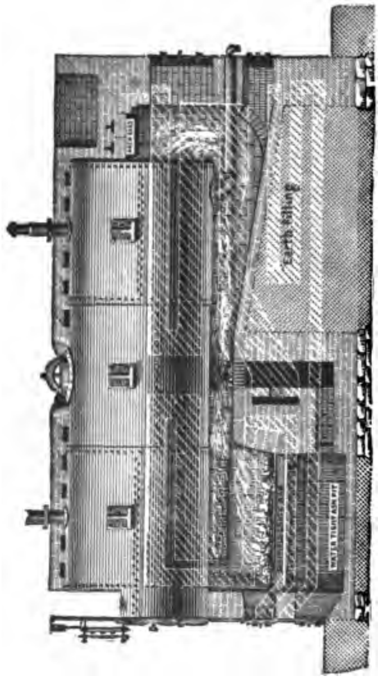


FIG. 53.—RETURN TUBULAR BOILER. (Jarvis setting.)

it easy for the fireman to get in. This will make him more likely to get in there often.

Q. What is the advantage of having water in the ash pit?

A. It largely prevents the passages in the flue, etc., from being clogged up with dust.

Q. Should the back wall of the boiler setting be formed by the wall of the boiler house?

A. No; the boiler setting should be formed entirely independent of all connection in the building.

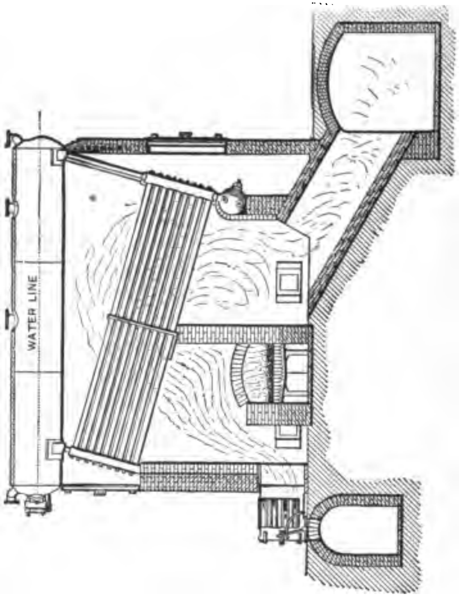
Q. Should there be openings in the back walls?

A. There should be at least one for access and to let light be admitted for inspection.

Q. How would you set an inclined multitubular boiler?

A. Set a brick wall in front having openings for furnace and ash pit doors; give these a fire brick lining inside, and if desired a cast iron front outside. Back of the grates run up a bridge wall to the bottom of the inclined water tubes, to drive the gases of combustion

among the tubes instead of letting them pass below them all. Lay a counter



wall from the top of the tubes to the back of the drum, this wall being car-

ried by iron bars or beams, or by perforated plates, and faced with fire bricks; and carry the lower and back ends of the tubes upon brick walls. Back of all have a back wall with suitable man doors; run up side walls and arch them at the top nearly up to the drum.

Q. Should the top of a horizontal boiler be left uncovered?

A. No; it is well to cover it with a brick wall having a dead air space between it and the top of the shell; leaving openings for the top man hole on the bottom, if these unnecessary features are provided; also for the steam pipes, safety valve, etc.

Q. What arrangement should be made in the brick setting to allow for inspection and cleaning?

A. There should be convenient openings left.

Q How is the current of gases in the return tubular boiler sent into the tubes?

A. By an arched wall of brick, or by a curved flue plate, the upper and front end of which is a little above the top row of tubes, and the lower and back end taken by an easy curve to the back wall.

Q. How is a vertical boiler set?

A. A foundation of stone is made, a little larger than the space that the base of the boiler takes up; then there is laid a large flat stone slab which distributes the weight, and at the same time serves for a safe bottom for the ash pit. Upon this there is set the base or frame of the boiler, which is a high cast iron ring having at the top a flange to receive the bottom of the boiler shell, and at its bottom another ledge to hold the grate. In front there is an ash door.

Q. How would you set a vertical boiler upon a wooden foundation?

A. Dig down a sufficient distance; lay one course of 2" plank; then another at right angles to this, and so on until there is a stiff enough foundation; put concrete upon the top of this and then a sheet iron or boiler plate covering, upon which the base ring is placed.

Q. How would you set a vertical boiler in the top story of a building, or upon a dock?

A. Provide a cast iron basin in which to place the base; keeping this basin filled with water in order to catch all

the live coals that might drop through the grate.

Q. Would you not anchor down your vertical boiler?

A. Not unless I should expect it to be liable to be overturned by a very high wind, or by being knocked by the boom of the crane, or some such happening.

Q. How would you prevent a vertical boiler from losing much of its heat by radiation into the air?

A. By giving it a jacket of some non-conducting material; a dead air space, or a crating of asbestos or some other material which will not jar nor let much heat pass through. Outside the asbestos I would use some other material that would be a better non-conductor. There are plenty of plastic coverings and also a great variety of other ways of making the last cover.

Q. What color should this outer covering be; and why?

A. White in every case, because this radiates less heat than any other color, other things being equal.

Q. Where is an ordinary cylindrical boiler without tubes or flues fired?

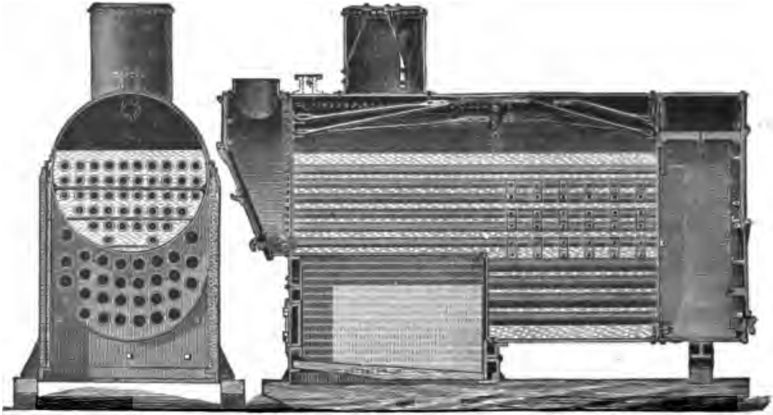


FIG. 55.—RETURN TUBULAR PORTABLE. (Erie City Iron Works.)

A. At one end, under the shell.

Q. If two boilers at different distances from the smoke stack, which one will have the poorest draft?

A. The one farthest from the stack.

Q. Describe a brick lined fire-box boiler?

A. In the construction shown, Fig. 55, the furnace is lined with fire-brick, the front end is cylindrical, and extends from the furnace. The rear end is oval, the lower portion extending below the cylindrical front part far enough to hold the short tubes leading from the furnace to the back connection. The furnace can be detached from the boiler, the lining being held in place by iron rods.

Q. Using saw dust as fuel, what should be the difference in the setting, etc., from furnace arranged for wood?

A. The best plan for burning saw dust (in large quantities) is to have the furnace extend further forward than the boiler, and have a feed "well hole," through which to introduce the saw dust, above the regular "stoking" doors. (This does not apply to so-called cedar

saw dust, which is often not granular but fibrous, more like "excelsior.")

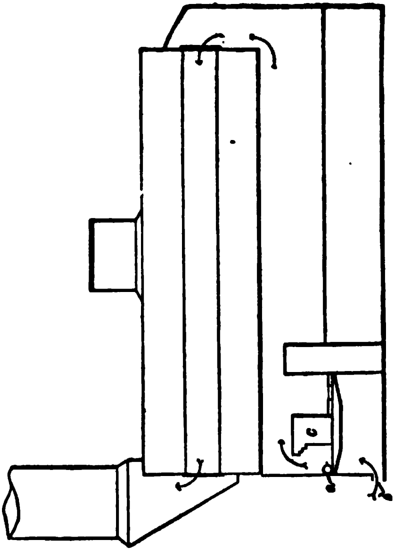


FIG. 56.—SETTING FOR NATURAL GAS.

Q. How would you alter an ordinary setting for a return flue boiler, for natural gas?

A. The sketch shows a setting so altered. The gas enters at *a* through a 3-inch pipe. The pipe is perforated with $\frac{1}{8}$-in. holes one inch apart; is placed inside the furnace wall, resting upon the grate as shown, and extends across the entire width of the furnace.

Air enters at *b*, by a number of openings twelve inches high by six in width, and is regulated by dampers. The air passes up and through the space between the grate bars underneath the gas.

Upon the grate a small bridge or wall (*c*) is erected, the front side of which is "stepped," which gives the gas and air a rolling motion, materially aiding their intimate mixture. The grate at the rear of bridge-wall (*c*) is covered with a course of fire-brick, as shown.

Q. How much gas pressure would you allow?

A. Eight to ten ounces is found sufficient for all needs.

SAFETY APPLIANCES.

Q. What are the safety appliances usually attached to a boiler?

A. Safety valve, gauge cocks (try

cocks), glass water gauge, and pressure gauge.

Q. What other safety appliances are less generally attached?

A. Fusible plugs, low water alarm, sounding gauge.

SAFETY VALVES.

Q. What should be the capacity of the safety valve?

A. It should be able to blow off at the pressure to which it is set (and which should be at or below the allowable legal pressure) all the steam which the boiler could generate under the most favorable circumstances, and without any steam being drawn from the boiler at the time by the engine.

Q. What area of safety valve is required for ocean and river service by the U. S. regulations?

A. "Not less than one square inch of area for each two square feet of grate surface," where a common valve is used; but where the lips will give an effective area of half that due to the diameter, then a half square inch of area is required for each two square feet of grate, which is another way of saying one-

fourth of a square inch per square foot, or one square inch to four square feet.

The following table gives the diameter of safety valves by the U. S. rule:

Grate Area. Square Feet.	Diameter for common Valve. Inches.	Diameter for Valve with effective area = ½ actual area.
5	1¾	⅞
6	2	1
7	2⅛	1
8	2¼	1⅛
9	2⅜	1⅛
10	2½	1¼
12	2¾	1⅜
14	3	1½
16	3¼	1⅝
18	3⅜	1¾
20	3⅝	1¾
22	3¾	1⅞
24	3⅞	2
26	4	2
28	4¼	2⅛
30	4⅜	2¼
32	4½	2¼
34	4⅝	2⅜
36	4¾	2⅜

Q. What is the maximum desirable diameter for safety valves; and why?

A. Four inches; because beyond this, the area and cost increase much more

rapidly than the effective discharging ring around the circumference.

Q. Should two boilers have a safety valve in common?

A. Never.

Q. Should there ever be a stop valve between boiler and safely valve?

A. No.

Q. What is requisite in safety valves?

A. Safety valves are of little use and no security unless they can discharge all the steam the boiler can make, with low water, best draft, and all other steam outlets closed. Not one in a hundred will fill this requirement.

Q. What is the velocity at which dry steam escapes into the air?

A. McFarland Grey states that dry steam above 11 lbs. gave pressure escape at a rate expressed by the formula: $W = P \div 70$, when W = the pounds of steam per square inch of opening per second and P = pressure in pounds per square inch above vacuum. Thus if the boiler pressure were 70 lbs. above vacuum, each square inch of opening would discharge 1 lb. of steam per second.

Q. Is the opening for the escape of

steam, with a conical valve, greater or less than the lift?

A. Less; for a cone of 45° the decrease is in the ratio of 7 to 10.

Q. Are rules for safety valve area based on heating surface of very much value?

A. No.

Q. What advantage have flat disc valves over conical?

A. Less likely to stick fast.

Q. What objections to the use of flat disc valves?

A. They are difficult to maintain at high pressures, and the fact that the escape of steam is at right angles to their lift.

Q. What should be the minimum angle for conical valves?

A. 45°.

Q. What objection to conical valves of less than 45°?

A. Liability to stick.

Q. Which is the best way to guide safety valve lids; inside wings, or a central spindle; and why?

A. Wings, as the spindle is liable to get bent or stuck.

Q. What advantage is the use of spherical safety valves?

A. They need no guides and are in consequence less likely to stick.

Q. How are safety valves held to their seats?

A. By weights or by springs, and either indirectly by levers, or directly.

Q. Where levers are used, what precautions should be taken?

A. The stem bearing pin, if there is one, should be loose under the lever, to avoid lateral thrust on the valve. It is best to have such pin act below the joint of the valve, in a suitable depression.

Q. What peculiarity about the leverage of a safety valve when the fulcrum is above the point where the load is transmitted to the pin?

A. As the valve rises, the leverage with which the load acts increases.

Q. How may the liability of the pins and bolts of a safety-valve, getting rusted or clogged, be lessened?

A. (1) By making the pins double-edges, or lever ends of gun metal; or, better yet, (2) by making the lever turn

on a case-hardened knife-edge; or, (2) by making the fulcrum a thin, short, flexible piece of steel, as in the Emery testing machine fulcrums.

Q. What objection to the lever safety-valve?

A. Ease of tampering therewith.

Q. How may overloading be in some measure prevented?

A. By cutting off the lever at a point just beyond where the proper "pee" or weight should rest; by permitting but one weight and having that of a special shape and painted a peculiar color; by not having the fork in which the lever rests bridged over at the top; and by having a pressure gauge, tested every three months, placed in the office and connected to the boiler by a pipe having no stop-cock within control of any one but the proprietor or superintendent.

Q. What facilities should be afforded for regrinding the valve in place?

A. It should have a square piece cast on the lid, by which to turn it around.

Q. In ascertaining the weight necessary to add to a safety-valve to balance a given pressure or the distance at which

a given weight must be placed, what must be taken into consideration?

A. The load on the valve, due to the weight of the lever and weight of the walve and pin.

Q. How may the leverage with which the lever acts, be measured?

A. By the distance of its center of gravity from the fulcrum.

Q. How may the center of gravity of the lever be found?

A. By balancing it on a straight-edge or on the end of a looped cord.

Q. How may the weight of the valve or pin be ascertained?

A. By direct weighing.

Q. What is the formula for finding the weight on the end of a safety-valve lever?

A.

$$W = \left\{ (P \times A) - \left(V + \frac{w \times g}{l}\right) \right\} \frac{l}{L}$$

where W= weight at the end of the lever, L the distance between weight and fulcrum, w= weight of lever, g= the distance of the center of gravity of the lever from fulcrum, P= the pressure in

pounds per square inch by the gauge (above atmosphere), V = weight of valve, and l = distance between valve center and fulcrum.

Thus: Supposing we have a lever, 48 inches between center of fulcrum and point of suspension of weight, a valve 4″ diameter, and weighing, with its pin, 6 lbs.; the pin-centre 3″ from the fulcrum center, the weight of lever 10 lbs.; its center of gravity 20″ from fulcrum; boiler pressure by the gauge 100 lbs.; then, as the area of the valve is $4 \times 4 \times 0.7854 = 12.566$ square inches, we have the required weight of "pee:"

$$\left\{ (100 \times 12.566) - \left(6 + \frac{10 \times 20}{3}\right) \right\} \frac{3}{48} =$$

$$\left\{ 1255.5 - \left(6 + \frac{200}{3}\right) \right\} \frac{1}{16} =$$

$$(1256.6 - 72.671 \div 16 = 73.99 \text{ lbs.}$$

If the weight of the lever and valve were not taken into consideration, the "pee" required would be 78.5 lbs., or 6.1 per cent. too much.

Q. How can one find the weight necessary to put on a safety-valve lever,

when the area of the valve, the boiler, pressure, etc , are known ?

A. By means of a spring balance, find the number of pounds pull requisite to lift the lever, unloaded and disconnected from the valve stem; the pull being

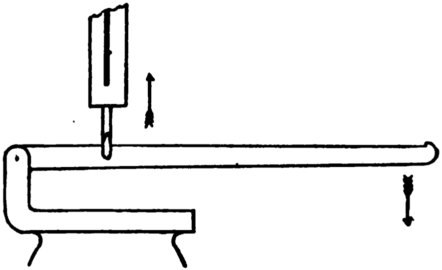


FIG. 57.—TESTING EFFECTIVE WEIGHT OF LEVER.

straight upwards and applied where the valve stem presses the lever.

Weigh the valve disk and stem.

Multiply the area of the valve in square inches by the pressure in pounds per square inch, to get the total upward pressure on the valve.

Subtract from this the weight of valve and stem and the *pull* of the lever on the spring balance. That gives the amount of downward pressure that must be put on by the ball (acting under leverage) pressure, the distance from the lever fulcrum to the point where the

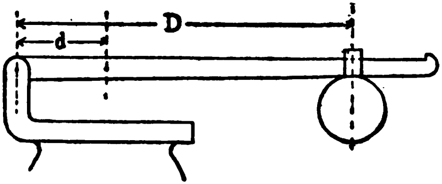


FIG. 58.—POINTS OF MEASUREMENT.

valve stem presses; also from the ful crum to point attachment of ball. Divide the first into the second. Divide the quotient into the amount of pressure required to be exerted by the ball under leverage; that will give the required weight of ball.

Q. How can one find the pressure per

square inch upon a safety valve when the area of valve, weight of ball, valve disk and stem, and distances between centres are known?

A. Find the downward pressure of lever alone as in the preceding rule. Add to it the weight of disk and stem. Multiply weight of ball by the leverage ratio. Add this product to sum of weight of disk, stem and pressure from lever. Divide the area of valve into this sum.

Q. How can the length of the lever be found when all the other conditions are known?

A. Find the weight of disk and stem; and the downward pressure of lever unloaded and disconnected. Find pressure of steam on whole area of valve. From it take the sum of the weight of disk and stem, and the downward pressure of lever. Divide the remainder by the weight of ball; that gives the leverage ratio. Multiply the distance d from fulcrum to point of application of stem, by this ratio, and that gives distance D, ball is to be hung, reckoning *from the fulcrum.*

Q. Should the lever of a safety-valve be level?

A. It should be horizontal, if the pressure calculated for a horizontal lever is to be put on the valve.

Q If the lever were inclined 20 degrees from the horizontal would the valve blow off at a higher or a lower pressure, with a given weight, than if the lower were level?

A. Lower.

Q. Should the centre of the hole in the fulcrum by means of which a bolt is inserted for fastening or holding the lever, be on a level with the top of the valve stem, or a little above or below it?

A. "The hole should be so placed that the bearing point of the lever at the fulcrum is level with the point of suspension of the weight."

Q. What should be done to the lever of the safety-valve when the proper place for the weight is found?

A. The extra length should be cut off.

Q. What can be said about the rise of safety-valves?

A. It diminishes as the pressure in-

creases, as the following table will show (from Burgh's experiments):

Table showing the rise of safety-valves in parts of an inch at different pressures.

Lbs.	12	20	35	45	50	50	70	80	90
Rise Inches.	$\frac{1}{36}$	$\frac{1}{48}$	$\frac{1}{54}$	$\frac{1}{65}$	$\frac{1}{86}$	$\frac{1}{85}$	$\frac{1}{112}$	$\frac{1}{168}$	$\frac{1}{168}$

Q. What is the average rise of ordinary safety-valves for pressures from 40 to 90 pounds?

A. From one-eightieth to one one-hundred and twentieth of an inch.

Q. What is liable to happen to the guide pin of a safety-valve?

A. It is liable to get bent.

Q. What about the joints of safety-valve stems?

A. They never should be rigid, but should have a ball joint.

Q. What is the construction and operation of a pop safety-valve for marine or stationary boilers?

A. In the Crosby, for instance, the valve proper rests on two flat annular seats on the same plane, and is held down by a spiral steel spring, the tension

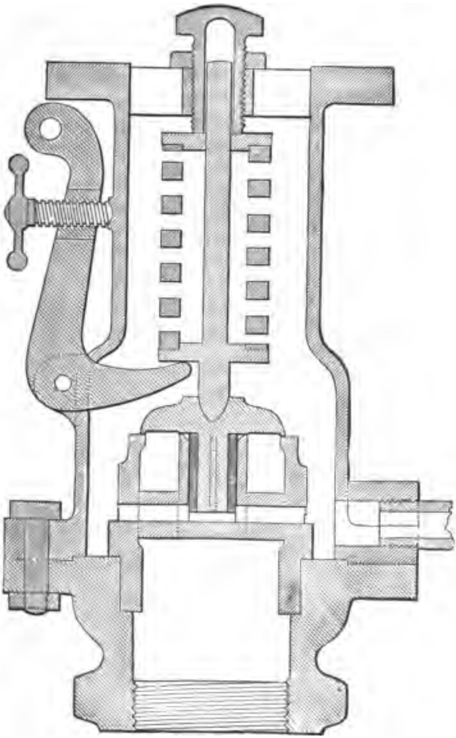


Fig. 59.—CROSBY POP SAFETY-VALVE.

of which is adjusted by a set screw. While the valve is seated, the annular area between the two annular seats gets all the pressure; but when it lifts, the area within the smaller seat is acted on. When the pressure reaches within about a pound of the maximum required, the valve opens slightly, and the steam es-

FIG. 60.—AMERICAN POP SAFETY VALVE.

capes under the larger seat into the cylinder surrounding the spring, then into the air; steam is also forced under the smaller seat into the well and theme, through the passages in the arms holding the inner seat, into the air. When the pressure reaches the desired maximum, the steam will be let into the inner

well faster than the passages therefrom will discharge it into the air; hence there will be an extra "differential" pressure

FIG. 61.—AMERICAN POP VALVE FOR STEAM FIRE ENGINES.

under the inner seat, lifting the valve wide open.

Q. With what can a leaking safety-valve be ground on its seat?

A. With powdered glass, or flour of emery, or the fine grit from the troughs of grindstones.

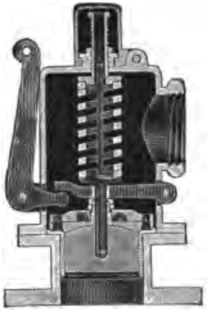


FIG. 62.—AMERICAN POP SAFETY-VALVE FOR MARINE BOILERS

Q. Describe a double-headed safety valve?

A. There is a second or movable head on top of the valve proper. There are two series of holes drilled around the

outer edge to reduce the amount of increased area; the first being around the head of the valve proper, and drilled at an angle of 90 degrees with its seat; the

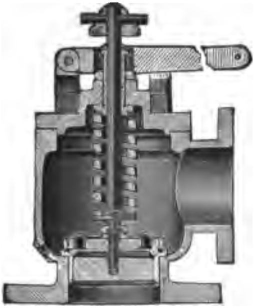


FIG. 63.—BOARD OF TRADE STEAM AND MARINE POP VALVE.

second series being around the movable head, and drilled at an angle of 55 degrees to those in the head proper. The movable head is so placed that there is a small opening between the two sets of

holes. When the valve lifts to blow, the second head is so forced around that the increased area is decreased.

Q. What peculiarities has the Board of Trade Standard pop valve?

A. Bevelled seats at an angle of 45 degrees; the valve proper can be turned on its seat (by handles shown above the lock-up cap) while steam pressure is on, to crush any sediment that might be on the seat. It can be taken apart and cleaned without disconnecting from boiler or escape pipe. The lower is so attached that it can be changed into any position, or at any angle with the valve.

Q. How is the Lynde lock safety-valve made?

A. Referring to the illustration:— *A* is the valve; *B* guide wings attached thereto, and connecting with the concave disc *C*. *D* is the rim against which the guide bears, *E* the guide pin to the valve. *K* is the nut by which, with the action of the lever, the valve is lifted from its seat when under pressure or otherwise. *H* is the pressure stud by which the valve is set to relieve at any pressure required. *I* is a check nut to

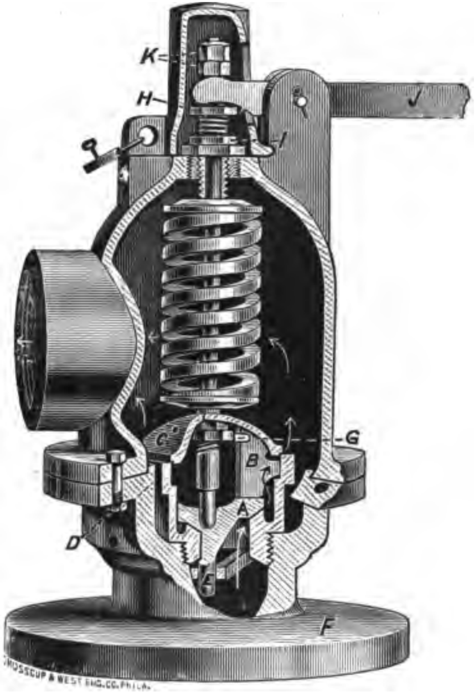


FIG. 64.—LYNDE SAFETY-VALVE.

make tight when the valve is set at the required working pressure, after which

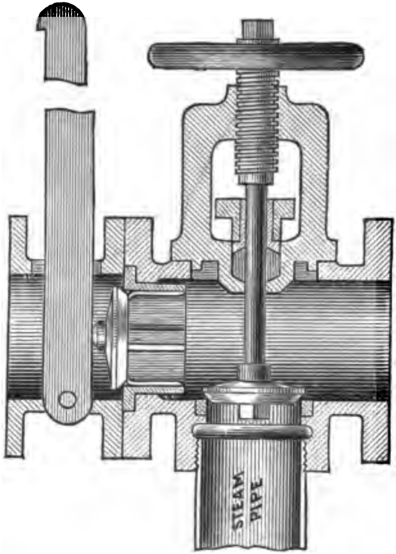


FIG. 65.—"ATLAS" COMBINED SAFETY AND POP VALVE.

the valve can be locked. The valve will open when the pressure at which it is

set is reached, thus reducing the pressure slightly, and should not allow it to increase if the valve is the proper size for the work it has to perform.

FIG. 66.—AMERICAN POP VALVE AND MUFFLER COMBINED.

Q. Describe a combined safety and stop valve?

A. The casting connecting with the boiler has two outlets; one at the top, closed by the safety-valve, and are at the

side controlled by an ordinary conical faced stop valve actuated by a hand wheel and screw. The safety-valve cannot be cut off from the connection with the boiler; and the arrangement necessitates cutting but one hole in the shell.

Q. How may the noise from blowing safety-valves be muffled?

A. By compelling the steam to pass through a great number of small slits or orifices, having a combined area much greater than the discharging area of the valve. If these slits are formed by adjacent coils of helical springs, their vibrations neutralize one another and the sound is muffled.

Q. How many square inches are there in a valve seat four inches in diameter? (Show the work).

A.

$$\begin{array}{r} .7854 \\ 4 \times 4 = 16 \\ \hline 47124 \\ 7854 \\ \hline 12.5664 = 12.57 \text{ sq. in.} \end{array}$$

Q. How many square inches of discharge area when that valve (supposing

it a flat disk) lifts $\frac{1}{8}$ inch? (Show the work).

A.
$$\begin{array}{r} 3.1416 \\ 4 \\ \hline 8)12.5664 = \text{circumference} \\ \hline 1.5708 \text{ sq. in. discharge area.} \end{array}$$

Q. Give some rule for estimating the diameter of the disk of a safety-valve for a boiler of 100 nominal horse-power.

A. The English Board of Trade Rules give $\frac{1}{2}$ to $\frac{3}{4}$ square inch per square foot of grate surface per nominal HP. This would give 50 square inches of valve, or 8″ diameter, for a boiler of 100 nominal HP.

Q. Is the rule all right?

A. No; the valve would be too big for any use.

PRESSURE GAUGES.

Q. Should a steam pressure gauge be applied to a steam pipe?

A. No.

Q. Where should the pressure gauge be applied?

A. To the top of the drum or boiler.

Q. How often should a pressure gauge be tested?

A. Every three months.

Q. Should a steam gauge be attached to the boiler by a straight tube?

FIG. 67.—HIGH PRESSURE GAUGE.

A. No; but by a coil of one turn, improperly called a "siphon," to catch the condensed water, and to prevent live steam from getting at the spring, which it might "set" and thus ruin.

Q. What are the three principal types of pressure gauges?

A. Those having a mercurial column, those having a tubular metal spring and

FIG. 68.—LOW PRESSURE GAUGE.

ordinarily called "Bourdon" type, and those having a diaphragm spring.

Q. What are the principal types of mercurial gauges?

A. Those having a "direct column" of mercury, necessitating about 2 inches of column for every pound pressure per

square inch, and those having "manifold" and "differential" columns.

Q. What is a manifold column?

A. One consisting of a series of U's forming a continuous tube, and each one doubling the pressure put on it or shown by it, by reason of the pressure put on it by the one next to it.

Q. Sketch and describe a differential mercury gauge?

A. The diagram shows a central vertical section. There is a double headed piston *h* which has a small head at the lower end to receive heavy pressures, while the larger upper head takes the lighter upper pressure of mercury in the reservoir *i*, which communicates with the tube *g*. If the upper head is 6″ in diameter and the lower one has only $\frac{1}{1600}$ area (about $\frac{1}{42}$ the diameter) then a rise of $\frac{1}{50}$ of an inch caused by the pressure below *h* causes the mercury in the tube *g* to rise 3 feet. Suitable diaphragms prevent leakage past either piston.

Q. How is an ordinary Bourdon pressure gauge constructed?

A. There is a brass tube, generally flattened, bent into nearly circular form

and this is fastened at one end, and at that end receives steam pressure, the

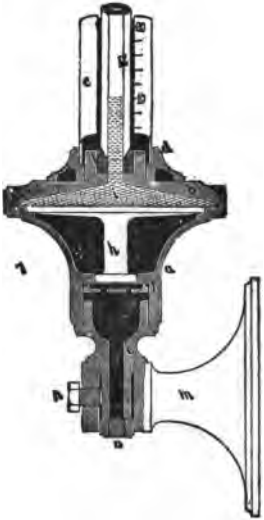


FIG. 69.—SHAW'S DIFFERENTIAL MERCURY GAUGE.

other end being closed and attached to a link which actuates a gear quadrant

reaching to the pinion of an index moving over a graduated dial. Internal pressure tends to straighten the tube, and the index records the amount of

FIG. 70.—ORDINARY BOURDON GAUGE.

strightening and consequent pressure Adjustment is by means of the pivot of the quadrant sliding in a radial slot therein.

Q. Do steam gauges generally get so

that they show too much or too little pressure?

A. Too much.

Q. What is the effect of letting steam touch the spring of a Bourdon steam gauge?

FIG. 71.—CROSBY-BOURDON GAUGE.

A. It expands the tube and gives too much movement.

Q. What mark should be put upon the steam gauge?

A. Plain mark, showing the highest pressure allowed.

Q. What sight test should be applied

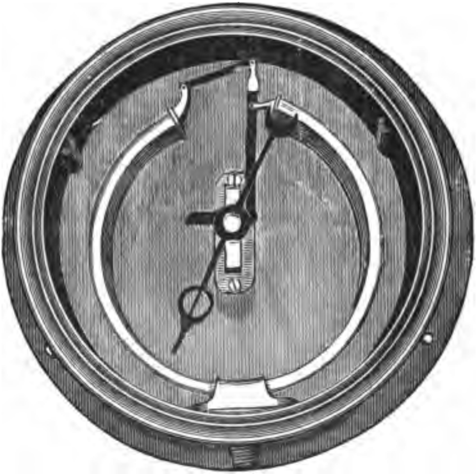


FIG. 72.—LANE DOUBLE SPRING GAUGE.

to steam gauges when there is no pressure upon the boiler?

A. It should be seen that the index points to zero.

Q. What attachment should be made to an ordinary steam gauge?

A. A two-way cock between the gauge and the boiler, to see that the finger points to zero when the boiler pressure is shut off and air let in into the gauge.

Q. Give a ready method for being always able to prove the correctness of your steam gauge.

A. Have ready another gauge (known to be correct) and a T piece or other connection, so that you can have the pressure on both gauges at once through a wide range of pressure.

Q. Why "through a wide range of pressure?"

A. Because a gauge may be right at one pressure and wrong at others, either above or below that.

Q. Is there any choice in regard to the position a gauge may bear to the boiler it is attached to? If so, state what it is.

A. The steam gauge should be set where it will not be affected by heat nor indirect pressure, and in some excellent practice is set on a column taken from one side of the boiler.

Q. Where should the gauge-pipe be taken from?

A. From the highest point possible, and without elbows, until its reaches the gauge.

Q. What pressure per square inch will a column of water 27 feet high with a temperature of 40° Fah., exert on a gauge?

A. Multiplying the head in feet by .434 gives 11.71 ℔.

Q. If the water was warmer would a column 27 feet high exert more or less pressure on the gauge?

A. Less.

Q. Suppose the 27 feet column of water at 40 degrees was heated so as to expand in the tube until it was 30 feet high; would the pressure on the gauge be more or less than before?

A. Neither. The weight cannot be expanded.

Q. Suppose the 27 feet column was tipped so as to make an angle of 45 degrees, what would its pressure be per square inch? (Show the work.)

A. $27 \times 27 = 729$; $729 \div 2 = 364.5$; $\sqrt{364.5} = 19.15$; $19.15 \times .434 = 8.31$ ℔.

Q. Show and describe the details of a recording gauge?

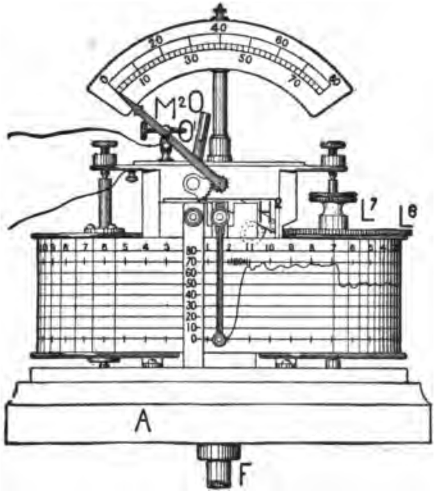


FIG. 73.—EDSON'S RECORDING AND ALARM GAUGE. (Elevation.)

A. There is a diaphragm D, Fig. 74, so corrugated that its movement under pressure shall be practically uniform for equal increases of pressure. From this

a connecting rod G actuates a small crank H, the shaft of which bears an open seg-

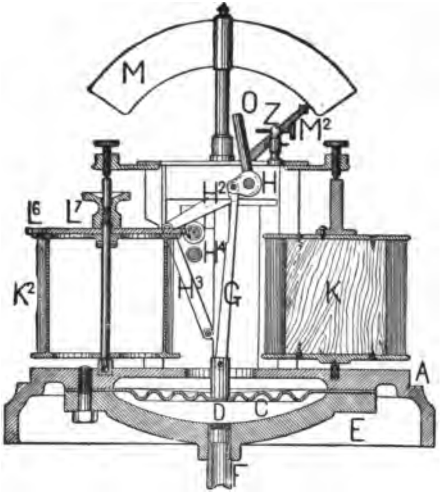


FIG. 74.—EDSON'S RECORDING AND ALARM GAUGE. (Vertical Central Section.)

ment, which actuates a pinion on the arbor of an index showing the pressure on the diaphragm. At the same time,

by means of levers H_2, H_3, vertical movement is communicated to a pencil point, which records gradually on a graduated paper ribbon the pressure shown by the index as being on the diaphragm. The paper strip has given to it by clock work a regular motion from the drum K to K^2, and has marked on it vertical spaces corresponding to hours. By this means, not only the index hand shows the pressure put on the gauge, but the pencil makes a continuous record showing all fluctuations and when they occurred. There is also an electrical alarm attachment by which when the pressure passes a certain limit, a bell is rung. This apparatus is kept in the office or whereever convenient, and is put in steam communication with the boiler.

Q. What do sudden and frequent fluctuations on the paper strip show, as regards safety?

A. That the boiler is being strained by unequal expansions.

Q. What do they show as regards economy?

A. That fuel is being wasted by irregular combustion and poor control.

TRY COCKS.

Q. How many gauge cocks (or try cocks, should a boiler have?

A. At least three.

Q. Where should the try cocks be placed?

A. One at the water line, one an inch above the crown sheet (or flue tops, according to the boiler), and one in the steam space.

Q. What class of try cocks are best for portable engines and for locomotives?

A. Compression cocks.

Q. How should the try cocks be placed?

A Diagonally above one another.

WATER GAUGES.

Q. What should be the position of the glass water gauge?

A. The lower stuffing box gland should be centered about an inch above the crown sheet or flue tops; the upper one a foot or so above.

Q. What precautions should be taken in applying glass gauges?

A. To provide means for shutting off the steam and water in case of breakage of

FIG. 75.—REGISTER'S TRY COCK.

the glass; to arrange to test and clear out the connections with a steele rod; to connect the upper part high up and the lower part low down.

Q How may gauge glasses be cut?

A. With a glazier's diamond; with the corner of a file, wet in turpentine; by applying a red hot thin iron ring at the desired line, and then chilling with cold water; by similarly making a heated circle around the tube by tying a turpentine thread around it, and setting this on fire; and by a regular gauge glass-cutter with small revolving wheel of chilled iron.

Q. At what height should the water gauge glass be attached?

A. At such a height that the proper water line will be in the centre of its length.

Q. How large a drip opening should there be for a $\frac{5}{8}$ inch gauge glass?

A. Not less than $\frac{1}{4}$ inch; larger would be better as giving better chance to clean the glass.

Q. How may the danger from escape of steam when the glass in the water gauge breaks, be avoided?

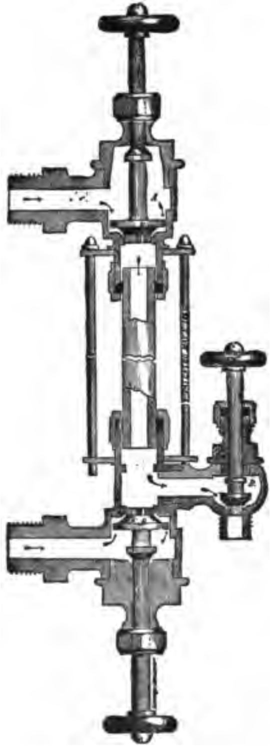


FIG. 76.—LANG'S AUTOMATIC WATER GAUGE.

A. By having automatic balanced valves to the fittings, so that when there is no outflow of steam, both the top, and the bottom valves remain open; but if there is a current of steam, both shut by reason of the unbalanced pressure.

Q. How is a simple automatic water gauge attachment made?

A. There is a ball valve at each opening; each ball lies quietly away from its seat, so long as there is pressure in the gauge glass; but so soon as the glass breaks, the balls are forced by the current against their seats, stopping the discharge.

Q. What makes good packing rings for gauge glasses?

A. For the top, asbestos wicking, slightly tallowed; for the bottom, asbestos wicking and candle wicking.

FUSIBLE PLUGS.

Q. What is a fusible plug?

A. A plug is some alloy which melts at a low temperature, screwed or riveted in the crown sheet or simliar spot. When covered with water it will not melt; when dry it melts in the steam and gives the alarm.

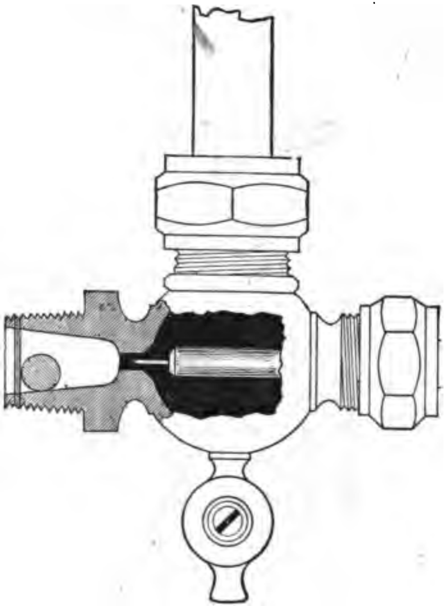


FIG. 77 —CROSBY AUTOMATIC GAUGE ATTACHMENT.

Q. How are fusible plugs often rendered inoperative?

A. By being wrongly set, or by being

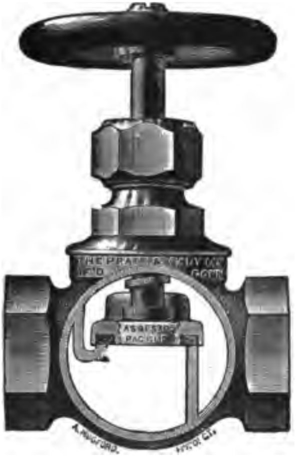


FIG. 78.—ASBESTOS PACKED GLOBE VALVE.

allowed to get coated with scale or sludge.

Q. What is the disadvantage of fusible plugs when improperly set?

A. They give false confidence.

CHECK VALVES.

Q. What is a check valve?

A. A valve which permits the passage of fluids in but one direction; as for instance, which allows the feed water to

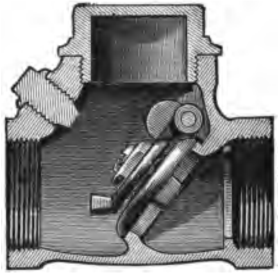


FIG. 79.—SWING CHECK VALVE

pass from the pump or injector into the boiler, but not back again.

Q. What should supplement the check valve on the feed water pipe?

A. A globe or plug valve between the check valve and the boiler, so that if the check sticks open or for other reason needs to be taken out, the stop valve

can be used. It is also prudent to close this stop at night in order to prevent

FIG. 80.—RENEWABLE SEAT CHECK GLOBE VALVE.

FIG. 81.—RENEWABLE SEAT GLOBE STOP VALVE.

the water from gradually leaking out in case the check was not tight.

Q. How may the useful life of stop valves and check-valves be lengthened?

A. By having renewable seats.

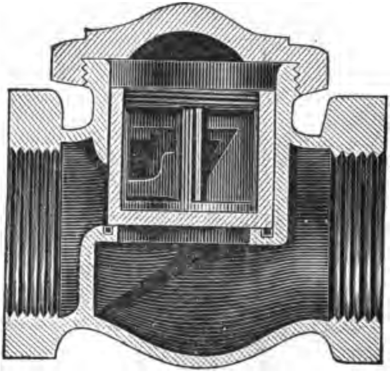


FIG. 82.—CHECK VALVE.

Q. Is there any advantage in having the check valve inside of the boiler?

A. Yes, in case of accident knocking off what projects, there is no hot water nor steam escaping from the boiler.

Q. Where are such inside check valves put?

A. In the back head, and the water is

carried forward by a tube, thus overcoming the necessity of mud and scale near the pipe.

Q. In putting in a straight way valve, how should it be faced?

A. So that the pressure will tend to keep it to its seat when closed.

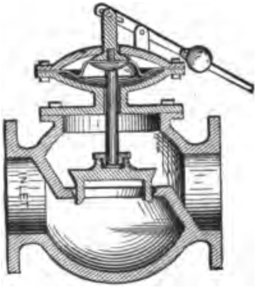


FIG. 83.—BACK PRESSURE VALVE.

Q. How about a globe valve?

A. So that the pressure will tend to raise it from its seat when closed.

Q. Why this difference?

A. Because the disk of a globe valve may be forced against its seat and held there under pressure while the gland is unscrewed and the stem packed.

BLOW OFFS.

Q. Where should the blow off be attached to the boiler?

A. There should be, besides one at the back end, just below the water level, as a scum blow, another at the back end as low down as possible, to permit the water being emptied.

Q. What objection is there to using a brass cock with an iron plug for a blow-off cock?

A. (1) Galvanic action; (2) leakage by reason of the brass shell expanding more than the iron plug.

Q. What is the surface blow-off for, and how arranged?

A. A pipe arranged so as to discharge the water at or near the water level; of use in discharging gases, or light solid matter which floats on the top of the water in the boiler.

TRAPS.

Q. With what should every range of steam pipes be provided?

A. With a means of draining the water of condensation from the end where the steam enters; also, if it is a

long run, of taking out the water and, if possible, returning it to the boiler.

Q. What is such a device called?

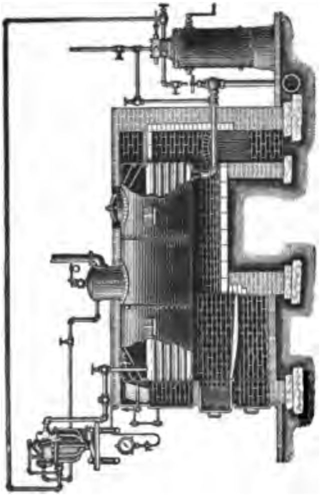


FIG. 84.—ALBANY STEAM TRAP IN PLACE.

A. A separator, if it is in direct connection with the boiler, and the steam from the latter strains through it; a trap, if it is attached to the pipe and

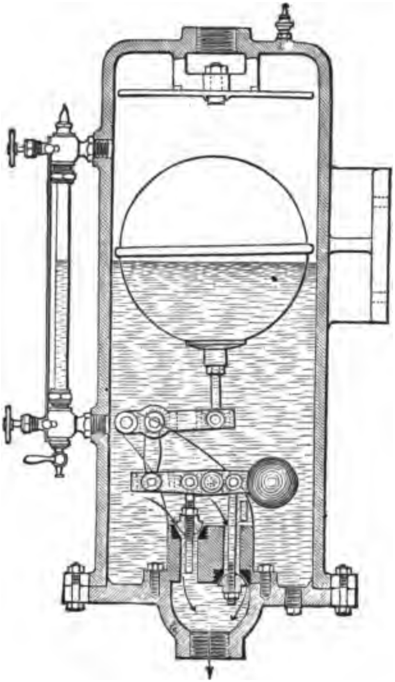


FIG. 85.---FOGARTY'S TRAP.

drains out the water from steam which has once left the boiler.

Q. What are the principal types of traps?

A. Expansion and float.

Q. Describe a float trap.

A. There is a vertical cylinder with flanged joint at the bottom; and attached to the bottom in the inside is a casting having two valve seats, one on its upper and one on its lower side; these being closed by hemispherical valves borne on spindles attached on different sides of the fulcrum of a weighted lever actuated by a float in the trap. The weight tends to close both valves; the float to open both. The drip enters at the top, a baffle plate keeping dirt from lodging on the float, and hence weighting and corroding it. When the water rises beyond to a determined point the float opens the valve and discharges the excess.

THE WHISTLE.

Q. How can the infernal nuisance of the ordinary steam whistle be mitigated?

A. By having three whistles tuned

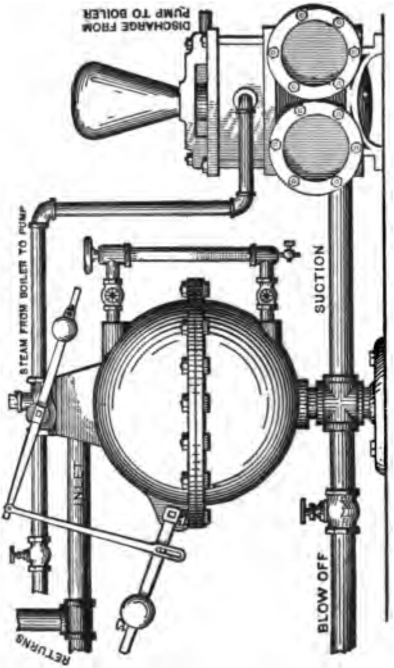


FIG. 86.—KIELEY'S TRAP.

to the first, third and fifth of the musical scale, so as to give a musical chord

when all are blown together; or by having the ordinary single whistle modified

FIG. 87.—CROSBY CHIME WHISTLE.

by dividing it vertically into three parts each with its own lip, and these parts

tuned to the first, third and fifth of the scale; as, for instance, sounding C, E and G respectively.

PRESSURE REDUCING VALVE.

Q. How may you use a boiler at very high pressure to boil water in a double tank in which the pressure must not exceed a certain amount, much below that of the boiler; or how may you connect two boilers, one having higher pressure than the other, without the high pressure of the one being put upon the other?

A. By means of a pressure reducing valve.

Q Give a sketch and description of a pressure reducing valve?

A. It is placed in the pipe the same as an ordinary globe valve, and the required pressure is obtained by means of the key, as shown in the sectional view. The high pressure steam enters at the side marked "inlet," and passing through the auxiliary valve *K*, which is held open by the tension of the spring *S*, passes down the port marked "from auxiliary to cylinder," underneath the

differential piston *C*. Raising the piston *D*, the valve *C* is opened against

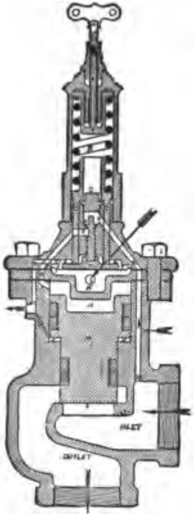


FIG. 88.—MASON'S PRESSURE REDUCING VALVE.

the initial pressure, and steam is admitted to the low pressure side of the valve,

whence it goes up the passage *X*, underneath the phosphor-bronze diaphragm *OO*, upon which the spring *S* bears. When the low pressure has risen to the required point, which is determined by the tension given by the key to the spring *S*, the diaphragm is forced upward, the valve *K* closes, and the valve *C* is forced on to its seat by the initial pressure, there being then no steam under the piston *D* to hold it up. This action is repeated as often as the pressure on the outlet drops below the required amount. The piston *H* is fitted in the dashpot *EE* to prevent chattering or pounding when the pressure suddenly varies.

GRATES.

Q. Should grate bars get their strength by depth or by width?

A. By depth.

Q. What is a tubular grate?

A. One made with circulation tubes instead of cast iron grate bars.

Q. With what kind of fuel are tubular grates used?

A. With anthracite.

Q. What are rocking grate bars for?

A. To obviate the difficult and exhausting labor of cleaning fires by slice bars and hook, and to save some of the coal lost in hand cleaning. They also tend to keep the fire level, and do not warp easily; and they do not chill the boiler by opening the fire-door when cleaning.

Q. Describe some form of rocking grate?

A. The bars in one kind quite well

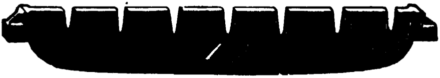


FIG. 89.—VAN DUZEN GRATE BAR.

known have extending cross-wise from them, fingers which in the ordinary working of the grate extend horizontally, on both sides of the bar, helping to form part of the grate surface. By giving the bars partial rotation first in one direction and then in the other, these fingers are made to lift first on one side and then on the other, thus cleaning the fire uniformly.

Q. Describe another form of cleaning grate?

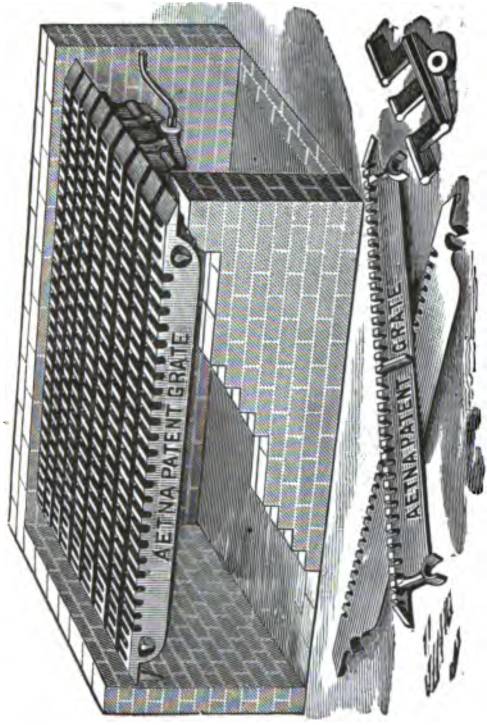


FIG. 90.—ROCKING GRATE.

A. There is one which is made in two sections—one for each door of the fur-

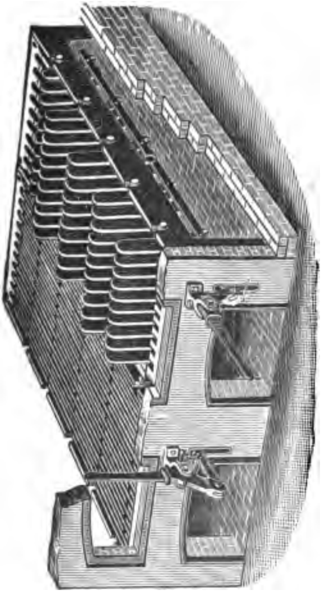


FIG. 91.—KIRKWOOD ROCKING GRATE.

nace. It has side frames connected at each end by a cross frame laid on its flat

side on lugs attached to the side frames and secured there by bolts. These side frames have recesses in which the wrought iron bars carrying the "fingers" are made to shake or dump as required. The fingers (16 inches in length) are made in small pieces of one or two fingers each to avoid uneven expansion and contraction. Their length and shape give a curved opening which, without permitting the small coal to fall through, enlarges the space. The shaker piece consists of an arm cast at its upper end to a finger piece and at the lower end is attached to the draw bar, which extends to the front, and by which the grate is shaken or dumped.

Q. Are rocking grates desirable for wood?

A. No; quite the reverse.

Q. Is a shaking grate the same thing as a rocking grate?

A. No; the rocking grate has a vertical motion, and the shaking only a horizontal.

Q. What are the proportions of grate to heating surfaces in the best marine practice?

A. From 1 to 25 up to 1 to 40. Upon the Arizona it is one to 25; Servia, 25.7; Monarch, 31; Oreste, 35.

Q. How wide air spaces may there be in the grates for lump coal?

A. About $\frac{3}{4}$ inch.

Q. How wide for dust coal?

A. About 5-16 inch.

Q. Which will allow the wider air spaces in the grate, anthracite or bituminous coal?

A. Anthracite.

Q. What causes grate bars to fail?

A. Breaking, warping, and burning out.

Q. What is necessary in a grate bar?

A. That it should have narrow surfaces exposed to the fire; that the air spaces should form a large proportion to the area, and that they be divided up and uniformly distributed.

Q. What will save grate bars very largely from destruction by too high heat in starting up?

A. Covering them with a very thin layer of coal before putting on the shavings and wood.

Q. Sketch in proper proportions and

dimensions part of a grate bar for successfully burning anthracite slack?

A. The grate successfully used under the Wootten locomotive boilers for that purpose, is of the width shown here; and

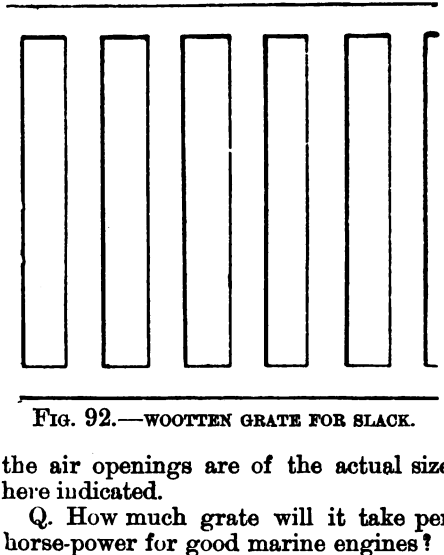


FIG. 92.—WOOTTEN GRATE FOR SLACK.

the air openings are of the actual size here indicated.

Q. How much grate will it take per horse-power for good marine engines?

A. The range is from 7.27 to 12.53

indicated horse-power per square foot of grate area. On the Arizona it is 8.08 horse-power per square foot of grate, there being 25 square feet of heating surface per square foot of grate.

DOMES, STEAM DRUMS AND MUD DRUMS.

Q. What is a dome?

A. A cylindrical enlargement or addition to the main shell of the boiler, generally having a flat top, though sometimes having a hemispherical or more nearly dome-shaped top.

Q. What is a dome for?

A. Nominally to serve as a reservoir for steam, and to help dry the steam.

Q. Is a dome of any real use as a reservoir for steam?

A. Little, if any. A cylindrical dome 24x36 inches on a boiler, serving two 18x24 cylinder, cutting off at 1-6, under 320 crank revolutions per minute, holds just enough for 16 strokes, or 3 seconds' supply.

Q. What disadvantages in the use of a dome?

A. Increased space taken up; greater cost; weakening of the shell.

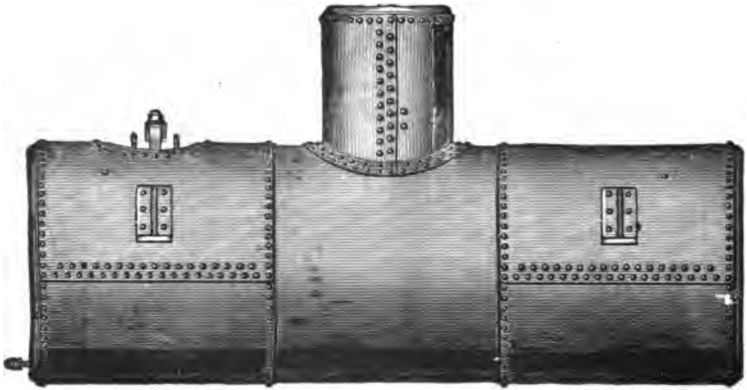


FIG. 93.—HORIZONTAL RETURN TUBULAR WITH DOME AND SIDE BRACKETS. (Lidgerwood.)

Q. What is the usual fault in dome construction?

A. Too large a hole in the main shell.

Q. What should be the size of the hole in the main shell, to supply the dome?

A. Twice the area of the steam pipe leading from the dome. That is, about 10.7 the diameter of that pipe.

Q. What is a steam drum?

A. A small cylindrical attachment to the steam space of a boiler, usually having flat ends or heads, and connected by one or more nozzles with the main shell. The steam supply pipe usually leads from the drum, when there is one. It may be either parallel with or at right angles to, the boiler proper.

Q. What is a mud drum?

A. A supplementary cylinder in which there is very little or no inculation, and in which mud and similar mechanical impurities are dropped, instead of being baked on the boiler sheets. See Figs. 94 and 95.

Q. What are the disadvantages of having one mud drum set across between two or more boilers?

A. You must blow off both or all the boilers at once.

DRY PIPES.

Q. How must dry steam be supplied?

FIG. 94.—CROSSWISE MUD DRUM.

FIG. 95.—LENGTHWISE MUD DPUM FOR REAR END OF BOILER. (Erie City Iron Works.)

A. It may be divested of much of its entrained water by passing it through a dry pipe which extends along the steam space and into which the steam must

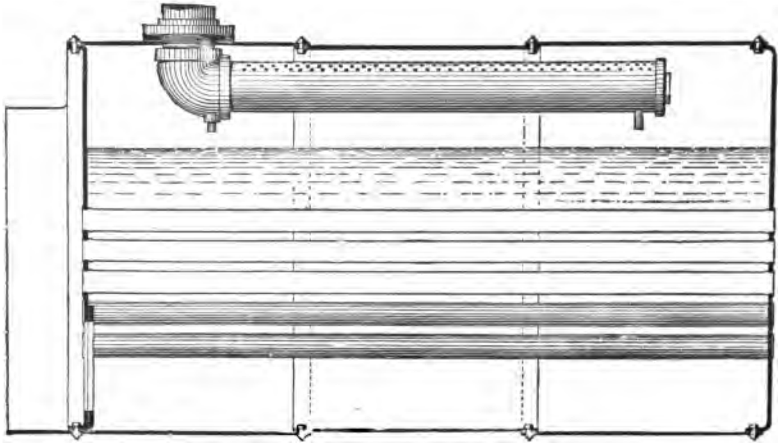


FIG. 96.—DRY PIPES.

enter through fine drill-holes or saw-kerfs. A long lead of vertical pipe generally drops a good deal of the water which would otherwise be driven into the horizontal reaches.

MAN-HOLES AND HAND-HOLES.

Q. Where should man-holes be cut?

A. Always in the flat head and never in the circumferential or convex part of the boiler.

Q. Where should hand-holes be put?

A. At the bottoms of legs, and in such places as to enable horizontal crown-sheets to be cleaned through them.

Q. Should man-hole plates and hand-hole plates be on the inside or the outside of the shell, and why?

A. Inside, so that the pressure of the steam tends to hold them tightly to the shell, and they cannot be blown off.

Q. What disadvantage is there in having the man-hole in the flat head?

A. It is less convenient of access than in the convexed portion, and it is apt to interfere with proper bracing, leaving a large space unprotected.

Q. What precaution should you observe in taking out the manhole plate or the handhole plate?

A. To mark the plate with a chisel at the top, to correspond with a similar mark upon the boiler, so that it will be put back in the same position as before being taken off.

Q. How are the man-hole joints made steam tight and water tight?

A. By gaskets cut of paper, canvas, sheet rubber, lead or copper.

Q. What action have "gum" or "rubber" gaskets upon the metal of the shell?

A. They tend to corrode it, by reason of the sulphur which they contain.

Q. How can you prevent soft gaskets from tearing and flaking when the joint is broken?

A. By calking or blackleading one or both faces; then they will not stick to either metal or surface.

CHIMNEYS.

Q. What is the stack or chimney for?

A. To make a draft, and to carry the

products of combustion to where they will be less annoying and injurious than if liberated at the ground level.

Q. Is the quantity of gas which a chimney will carry off greater as the temperature of the gases in the chimney increases?

A. No; there is a maximum at about 550° F.; but even at that point, the quantity is only about 4 per cent. more than at 300°.

Q. What would you consider the maximum draft that could be got in a chimney?

A. That corresponding to about 2″ of water.

Q. How high a chimney would that take?

A. About 167 feet.

Q. How do you figure that out?

A. By dividing the required draft in inches of water by .0075, thus:

$1.25 \div .0075 = 167 +$ feet: (better allow 175).

Q. How do you get the maximum draft in inches of water, for any chimney?

A. Supposing the heated column 612°

and the external air 62°, multiply the height above grade in feet by .0075, and the product will be the draft power in inches of water. Thus a stack 150 feet above the grade will have, when the column of gases is 612° F, and the external air 62° F, a draft of 150 × .0075 = 1.125 inches.

Q. Would that be enough to burn anthracite slack?

A. No, because that takes about 1¼ inches.

Q. How much coal should a chimney 80 feet high, 42 inches diameter, be able to take care of properly?

A. About 120 pounds of coal per hour per square foot of area of chimney.

Q. Can you give a table of sizes of chimneys with appropriate horse power of boilers?

A. The following table is made by William Kent on the assumption that there is a layer of 2″ of air upon the inside surface, that does not move; and that a commercial horse power takes five pounds of coal per hour:

SIZES OF CHIMNEYS WITH APPROPRIATE HORSE-POWER OF BOILERS.

Dia. in inches.	HEIGHT OF CHIMNEYS, AND COMMERCIAL HORSE-POWER.											Side of square inches.	Effective Area square ft.	Actual Area square ft
	50 ft	60 ft	70 ft	80 ft.	90 ft.	100 ft.	110 ft.	125 ft	150 ft.	175 ft.	200 ft.			
18	23	25	27									16	0.97	1.77
21	35	38	41									19	1.47	2.41
24	49	54	58	62								22	2.08	3.14
27	65	72	78	83								24	2.78	3.98
30	84	92	100	107	113							27	3.58	4.91
33		115	125	133	141							30	4.48	5.94
36		141	152	163	178	182						32	5.47	7.07
39			183	196	208	219						35	6.57	8.30
42			216	231	245	258	271					38	7.76	9.62
48				311	330	348	365	389				43	10.44	12.57
54					427	449	472	503	551			48	13.51	15.90
60					536	565	598	632	692	748		54	16.98	19.64
66						694	728	776	849	918	981	59	20.83	23.76
72						835	876	934	1028	1105	1181	64	25.08	28.27
78							1038	1107	1212	1310	1400	70	29.73	33.18
84							1214	1294	1418	1531	1637	75	34.76	38.48
90								1496	1659	1770	1893	80	40.19	44.18
96									1876	2027	2167	86	46.01	50.27

Q How does the friction of gases in a chimney operate?

A If you mean to what degree, its effect is the same as making the chimney flue smaller in cross section. There is assumed to be a layer of gases around the inside of the chimney bore or flue, about 2 inches in thickness, no matter what the size of the chimney; so that if you have a chimney with a flue of 24 inches in diameter, you will only have the effect of one 20 inches in diameter.

Q. What is the best way to arrange the top of a brick chimney in a quarter where there are variable winds, and there are likely to be down draft?

A. There are cast iron caps made which will make a draught of the chimney, no matter which way the wind blows—north, south, east, or west, up or down.

DAMPERS.

Q. What is a damper for?

A. To lessen the drafts by obstructing the chimney passages.

Q. What is the most common form of damper?

A. A "butterfly" or balanced disk.

Q. How are dampers made automatic?

A. By attaching them to a pressure device (diaphragm or piston) which mechanically closes the damper when the pressure reaches the desired point, fixed beforehand.

Q. What are the advantages of a good damper regulator?

A. The steam pressure is more regular, hence also the engine speed is, too; the strains on the boiler are more uniform; and there would be less danger of explosion with one than without it.

FEED WATER.

Q. Into what classes may feed water be divided?

A. Fresh and salt.

Q. How may fresh water be classed?

A. Into "soft" and "hard."

Q. What is "soft" water?

A. That which contains little or no mineral substance in solution; practically, rain water.

Q. What is "hard" water?

A. That which contains mineral substances in solution.

Q. What is the test for softness or purity?

A. Soft or pure water will not curdle Castile soap; hard water will.

Q. Which is the best for boilers, soft or hard water?

A. Soft.

Q. What are the most common mineral ingredients in hard water?

A. Salts of lime, magnesia, and iron.

Q. What are the most common lime and magnesia salts in feed water?

A. The carbonates, though the sulphates are found also.

Q. What other substances are found in hard water?

A. Silica, alumina, salt, etc.

Q. What is carbonate of lime?

A. It exists as chalk, as limestone, and as marble.

Q. How does carbonate of lime get in feed water?

A. By being dissolved by the springs which supply the source of the feed water.

Q. What is sulphate of lime?

A. Commonly known as gypsum, or plaster of Paris.

Q. What peculiarity is there about the solubility of sulphate of lime?

A. It is soluble at 95° F., and insoluble at 290° F. (being the temperature of steam at 40 lbs. per square inch).

Q. What is there in sea-water?

A. It is principally a strong solution of common salt, but the water of different seas varies in strength and ingredients. It averages about 3½ % of saline matter, or about 250 grains per gallon.

Q. What sea has the least salt in it?

A. The Baltic, which has only 6.6 parts in 1000, by weight.

Q. What are the next freshest?

A. The Black, with 21.6 parts per 1000; then the Arctic. with 28.3 and the Irish with 33.76.

Q. What is the general effect of bad water upon locomotive boilers?

A. To crack the fire-boxes.

Q. Do ocean steamships use salt water in their boilers, or how is the salt extracted?

A. Ocean steamships use surface condensers in which the steam used in the cylinders is condensed, and the water returned to the boilers.

Q. Is clear water necessarily good for a boiler?

A. No; that which contains carbonic acid is very often the clearest that can be found; and the same way with other substances which tend to corrode a boiler.

Q. What is the injurious effect of using Croton water in boilers?

A. None, if the boilers can be cleaned; otherwise it would cause incrustation.

Q. What is the effect of carbonic acid upon the solvent power of water?

A. Water containing carbonic acid will dissolve many mineral substances very readily.

Q. What is the effect of heat upon such water containing mineral sub stances in solution?

A. At a boiling temperature, the carbonic acid is given off, and the mineral substances are in very large part deposited as a precipitate.

Q. Where should the feed water be introduced in a boiler?

A. The feed water should be introduced at the bottom of the boiler, and preferably at the back end where the circulation is least.

Q. What is the objection to introduc-

ing the feed-water in a spray in the steam-space?

A. Introducing the feed-water in a spray in the steam space condenses some steam, and causes the rest to be wet.

Q. "Where is the best place to feed a tubular boiler that is sometimes fed with cold water and sometimes with hot?"

A. I would advise feeding about one-third or one-quarter the length of the boiler from the back end, above the tubes as far as possible and yet keep well below the water line.

Q. Is the water-level in a boiler really level?

A. It is apt to be higher over the furnace than elsewhere; particularly if the firing is hard.

Q. Which keeps the feed line more regular, a pump or an injector?

A. A pump, particularly if it be driven from the engine direct.

Q. How about firing when feeding?

A. It should not be done; for feeding is done by fits and starts; but if there is continuous feed.

Q. "Is it the custom on the Sound

and river steamers around New York harbor, when arriving at port, to blow off steam, and attach a connection with the Croton or other supply, allowing it to run for a long time, to change the water in the boiler?"

A. Most Sound steamers feed from the hot well steadily, the later ones having surface condensers. They carry fresh water tanks.

Q. "Is it the practice on boats to keep a steady feed, or do they pump when they have plenty of steam, and shut off when it goes down?"

A. Steady feed.

FILTERS.

Q. What is the use of a filter?

A. To withhold from the boiler such mechanical impurities as would thence enter it with the feed.

Q. What is a cheap filter to make for muddy water?

A. Hay or an equivalent in a closed vessel, through which material the feed passes, the mud being strained out. The hay is cheaply and easily changed when too foul.

Q. What other filtering materials are

good for straining mechanical impurities from feed water?

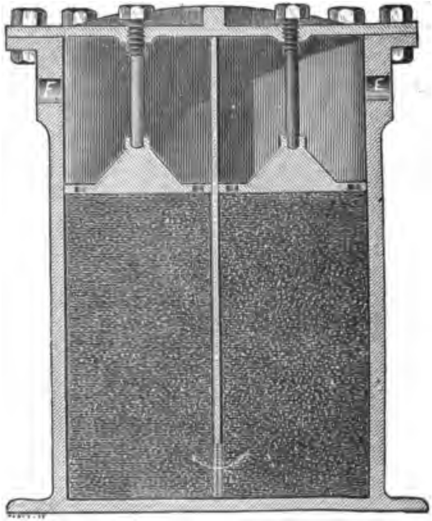


FIG. 97.—WAINWRIGHT FILTER.

A. Gravel, coarse sharp sand, broken charcoal, coarsely crushed bricks, sponge, etc.

Q. How is the Wainwright filter constructed?

A. As in Figs. 97 and 98. The water enters at E, and passes downward

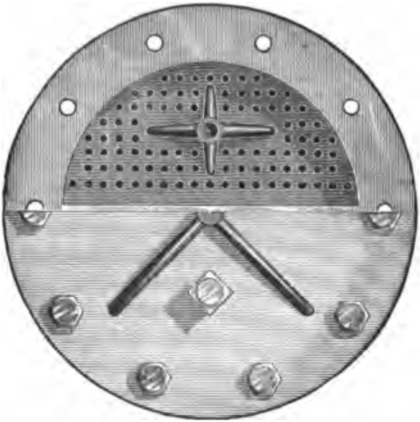


FIG. 98.—WAINWRIGHT FILTER.

through a semi-cylindrical division of the shell, a mass of animal charcoal, then under the diaphragm and upwards through another lot of charcoal, leaving at F. The filtering material is kept

compact by perforated plates held down by set screws.

Q. What is the Hyatt filter?

A. It uses as filtering material, sand and comminuted coke; a trifle of clay is

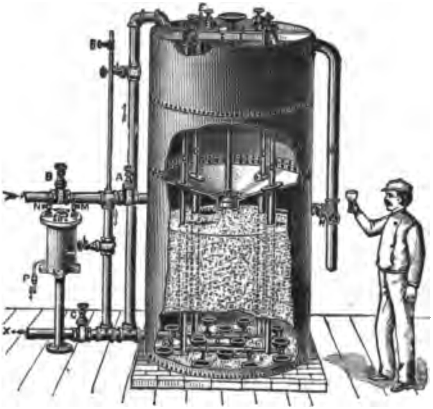


FIG. 99.—HYATT FILTER.

first added to the water to entangle the impurities, which are then removed by the filtering materials. The water enters the clay from the vessel T, enters the filter at A, and leaves at the bottom,

through outlet cone valves, K, passing along through X. The filtering material may be washed by closing the regular inlet and outlet valves A and C, opening the valve E at the top, and opening the valve L which connects the valves and outlet pipes. The water then passes up through valves K, loosens the coke and sand, and discharges them in the upper tank, which should be full of water. The dirtied filtering material dirties and displaces this water. Then close L, and open the centre valve F to let the coke and sand back into the filter.

Q. Can you describe a filter having mechanical means of refreshing its power?

A. In one form, the filtering material is stirred up when desired by two endless chains or sprocket wheels driven by a crank from the outside; and the perforated plate at the bottom has its holes kept free by pins on a plate below it; the same motion which stirs up the filtering material actuating, by an eccentric, this cleaner-plate.

Q. What is the Wass grease, air and mud extractor?

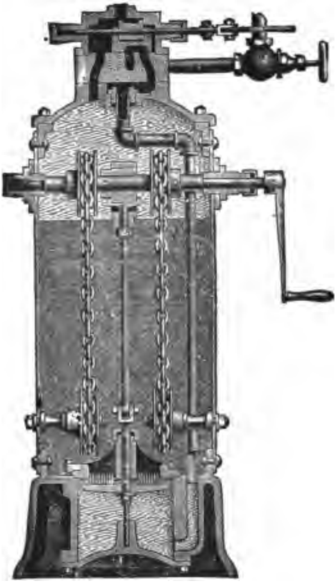


FIG. 100.—ALBANY FILTER.

A. It consists of a cast iron shell having traverse partitions extending alternately from the top and the bottom, partly

FIG. 101.—"WASS" GREASE, AIR AND MUD EXTRACTOR.

across its whole height. The water line is above the tops of the upwardly pro-

jecting partitions. Grease rises to the top of the water, and is blown off through an oil-discharge; solid matter is precipitated to the bottom; the air is discharged intermittently at the top by an air discharge valve worked by a float. There is generally a "by pass" to cut the apparatus out when desired to inspect or clean it.

MECHANICAL BOILER CLEANERS.

Q. What is a "mechanical" boiler cleaner?

A. One which by mechanical means only collects and removes from the boiler impurities which are suspended in the water.

Q. Describe such a device?

A. There is a funnel held in the boiler with its mouth facing front, and mostly above the water line but its apex below low water level. From the apex a tube rises and leaves the boiler, entering at one side of the top of a hollow cast iron sphere, having a vertical partition extending downward half way across it. From the other side of the top of this globe a tube goes through the boiler, entering

below the water line. The mechanically suspended impurities are by the circula-

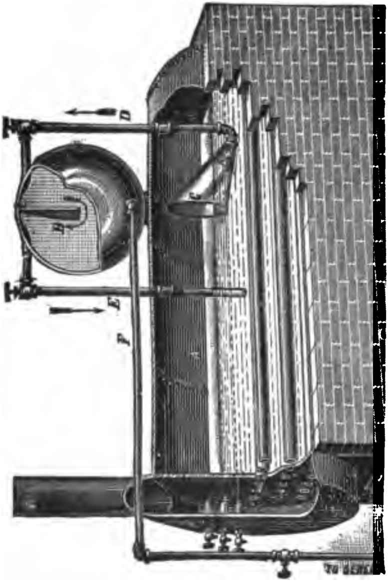


FIG. 102.—HOTCHKISS MECHANICAL BOILER CLEANER FOR HEAVY IMPURITIES.

tion in the boiler swept backward; carried up into the globe, and there finding a

large quieting or setting chamber, are dropped; the water going on back into

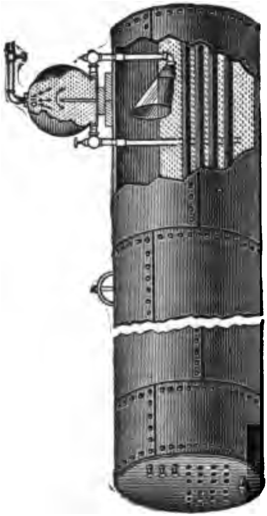


FIG. 103.—HOTCHKISS MECHANICAL BOILER CLEANER FOR OILY IMPURITIES.

the boiler. The globe has suitable shut offs and blow offs.

Q. How could such an arrangement be used for oily impurities?

A. The globe is reversed, so that the partition projects upward from the bottom, and the blow off is at the top, and the inlet and outlet pipes at the bottom.

HEATING THE FEED WATER.

Q. Can you refer to a table showing how much coal may be saved by heating the feed water—outside of the question of back pressure on the engine?

A. The table on opposite page gives the amount of saving for various temperatures of feed before and after heating; steam being supposed at 60 lbs. For other steam pressures the proprotionate saving would be greater, the lower the pressure.

Q. How hot may feed water be heated by the use of exhaust steam?

A. That depends on the temperature of the exhaust and of the feed before heating; on the purity of the feed, and on the efficiency of the heater. A few heaters will heat the feed to over 212° F. (an apparent paradox) by exhaust steam solely, without adding back pressure. Ordinarily, 180° is good work. The hotter the feed before heating, the

PERCENTAGE OF SAVING OF FUEL BY HEATING FEED-WATER.

(Steam at 60 lbs.)

Temp. after heat'g.	TEMPERATURE OF WATER BEFORE HEATING,												
	32°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°
60°	2.39	1.71	0.86	0									
80	4.69	3.43	2.59	1.74	0.88	0							
100	5.79	5.14	4.32	3.49	2.64	1.77	0.90	0					
120	7.50	6.85	6.05	5.23	4.40	3 55	2.68	1.80	0				
140	9.20	8.57	7.77	6.97	6.15	5.32	4.47	3.61	1.84	0			
160	10.90	10.28	9.50	8.72	7.91	7.09	6.26	5.42	3.67	1.87	0		
180	12.60	12.00	11.23	10.40	9.68	8.87	8.06	7.23	5.52	3.75	1.91	0	
200	14.30	13.71	13.00	12.20	11.43	10.65	9.85	9.03	7.36	5.62	3.82	1.96	0
220	16.00	15.42	14.70	14.00	13.19	12.38	11.64	10 84	9.20	7.50	5.73	3.93	1.98
240	17.79	17.13	16.42	15.69	14 96	14.20	13.43	12 65	11.05	9.37	7.64	5.90	3.97
260	19.40	18.85	18.15	17.44	16.71	15.97	15.22	14.45	11.88	11.24	9.56	7.86	5.96
280	21.10	20.56	19.87	19.18	18.47	17.75	17.01	16.26	14.72	13.02	11.46	9.73	7.94
300	22.88	22.27	21.61	20.92	20.23	19.52	18.81	18.07	16.49	14.99	13.37	11.70	9.93

greater the back pressure; the more impure the feed by reason of salts contained therein—the hotter you can get the feed.

Q. What is the advantage of using live steam in the feed water heater? Is it not just "taking money out of one pocket and putting it in the other?"

A. No; the high temperature in the heater causes the water therein to drop some of its impurities—as, for instance, sulphate of lime—which are not precipitated at any temperature attainable by exhaust steam. It is better to drop these substances in the heater than in the boiler.

Q. Are open feed heaters efficient?

A. Generally.

Q. Are they desirable?

A. Not always, because they often give trouble on account of the grease carried over from the cylinders.

Q. What are their advantages?

A. Ease of inspection and cleaning; absence of back pressure on the engine.

Q. Sketch and describe a coil feed heater?

A. One make consists of a vertical

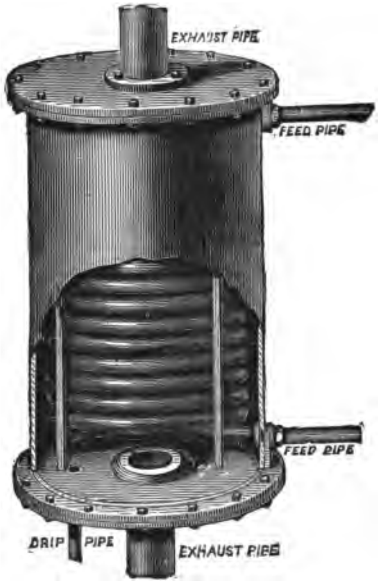


FIG. 104.—"NATIONAL" FEED HEATER.

cast iron cylinder with flanged top and bottom. The exhaust enters at the bottom and leaves at the top. The feed

runs through a seamless drawn brass coil, entering at the bottom and leaving at the top of the shell.

Q. Sketch and describe some other coil feed heater, using exhaust steam?

A. There is a cast iron cylinder with removable flanged top, and having an inclined false bottom, as shown. The feed coil is of corrugated brass tubing, and commences at the center of this false bottom, passing out at the top of the wall of the shell. The exhaust enters at the side where the false bottom is the lowest, and passes out at the center of the top. The space below the false bottom is a settling chamber or mud space, and has suitable blow-off.

Q. Can you describe the Robinson heater?

A. The heater proper consists of a vertical shell, through which a series of tubes run, the middle one being the largest. This shell is surrounded by another shell or jacket, with a small annular space only between the outside of one and the inside of the other, while at top and bottom quite large chambers are enclosed. The exhaust pipe "A"

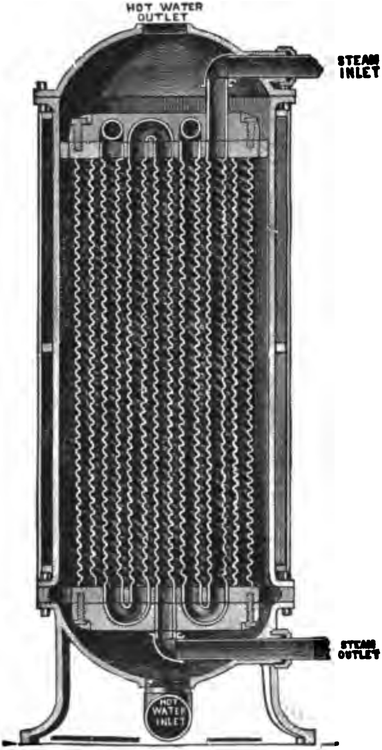


Fig. 105.—WAINWRIGHT'S CORRUGATED COIL HEATER.

from the engine, enters the bottom of the jacket and passes up through the large center tube "B" to or near its upper end. The exhaust steam passes up pipe "A" into chamber "E," thence down through the tubes of the heater, and also between the heater and jacket to chamber "K" and into pipe "I," whence it may be allowed to escape the atmosphere or be used for other heating. The water is forced in through pipe "H" and passes out to the boiler through pipe "G."

The heater should contain water enough to supply the boiler for twenty minutes, which is claimed to be more than sufficient time to allow the water to be heated to the boiling point, and to permit the impurities to either rise to the top or sink to the bottom. A quite large space "D" is left without tubes. The currents of water in the heater are upward along the tubes, and downward in the space "D." All impurities should be carried to this space and can be blown out through the pipes "O" and "J." The makers claim that the steam from the pipe "A," escaping in a vertical di-

FIG. 107.—STILWELL'S LIME EXTRACTING HEATER AND FILTER.

rection into chamber "E," and leaving it in the reverse direction, fills the chamber full; and that all the tubes, and the

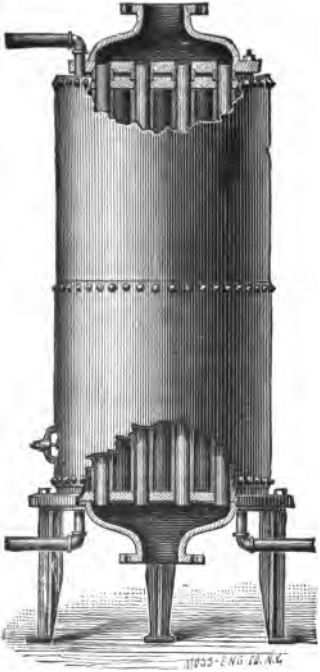


FIG. 108.—LOWE VERTICAL HEATER.

space surrounding the heater are equally supplied, so that they are always full while the engine is in motion.

Q. Can you describe a lime extracting heater and filter?

A. In the one shown, Fig. 107, the exhaust steam enters at the side, about half way up, and is divided into two currents. Part of it escapes at the top. The feed is partly sprayed in just above where the steam enters; and it trickles along in a zig zag downward course, over removable corrugated shelves or depositing surfaces, occupying nearly the central third of the height of the filter. Below this, the cylinder is filled with filtering material (had or something like that) which rests on a false bottom, below which the sediment may be removed. The feed, now heated, filtered, and deprived of its lime salts, escapes at the side of the filtering part of the apparatus. A steam tight door permits of the withdrawal of the pans when covered with lime.

Q. If there is a closed heater, should there be a pump between the heater and boiler?

A. No; the pressure of the pump should be upon the water before it gets

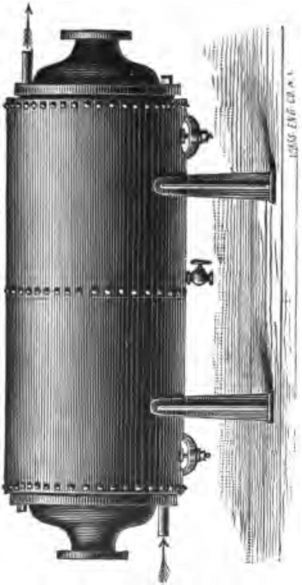


FIG. 109.—LOWE HORIZONTAL HEATER.

to the heater, because cold water is easier to pump than hot.

Q. What is an "economizer?"

A. The term is generally understood to mean a device for heating feed water by the chimney gases.

Q. What is the temperature of the escaping gases in chimneys?

A. Generally about 600° F.

Q. What is the difference between adding an economizer and putting more heating surface in the boiler?

A. In the economizer the feed water may enter, cold as ice, without injury to the apparatus.

Q. Where should the cold water be fed into an economizer; and why?

A. At the point farthest from the boiler, where it will get the coolest gases, and so it can get hotter as it goes on towards the boiler.

Q. Where will sediment deposit most readily, in an "economizer" or in a boiler?

A. In an economizer.

Q. How may an economizer be cleaned without stopping the boiler?

A. By having a direct flue from the boiler to the chimney, independent of the one around the economizer.

FEED PUMPS.*

Q. What is the construction of a feed pump, and the principles on which it lifts the water?

A. That is a question which should be broken up into a dozen or more, in order to get a proper answer. As a general reply, it may be said that in a lifting feed pump there is a cylinder in which there fits a water-tight piston; there is a valve which permits the entrance of water to the cylinder, but will not let it pass back again; and one which will let the water out of the cylinder, but will not let it back again (there may be more than one inlet valve and more than one discharge valve). When the piston makes a stroke in one direction, the unbalanced pressure of the air on the surface of the water to be lifted, forces it into the space left between the first position of the piston and its second at the end of the stroke (this space or volume being equal to the area of the piston

*The author, having published a Pump Catechism, uniform in size, style and price with this work, does not deem it desirable to go very deeply into pump details in this Boiler Catechism, but refers to the companion volume.

times the length of its stroke). When the piston makes a stroke in the reverse direction, returning to its first position, the inlet valve closes and an amount of water equal to that which was let in during the first or suction stroke is driven through the discharge valve.

The unbalanced pressure of the air on the surface of the feed water causes the filling of the pump on one stroke, and whatever force the piston is moved by on the return stroke, causes the discharge of the water (against the boiler pressure if there be steam on).

Q. What are the principal kinds of boiler feed pumps?

A. As regards the mode of driving they may be direct driven from the engine cross-head or other moving part; or belt driven, or gear driven; or they may be independent of the engine. They may be lifting or non-lifting; single or double acting; single cylinder or duplex. In any case the feed pump is one of the most important adjuncts, and the one which generally needs the most knowledge and skill on the part of the fireman, and gets the least.

ROBINSON'S HEATER IN PART SECTION.

Q. What is the best way to have a feed pump arranged, where there is both lift and force?

A. To discharge into a tank holding at least half a day's supply, so that if there is any accident to the lift, there will be time to look at the suction.

Q. What should be put on the foot of a lifting feed pump?

A. A strainer and a foot valve.

Q. What is the object of a foot valve?

A. To enable the pump to start off easily and promptly instead of having to fill the suction pipe each time of starting.

Q. In the ordinary boiler feed pump, what is the proportion between steam and water cylinders?

A. About 4 to 1 in area, or 2 to 1 in diameter.

Q. What is the effect on the pump, of the check-valve getting stuck open?

A. There is not necessarily any effect, if the pump has proper discharge valves. There is this disadvantage, that if anything happens to anything connected with the pump, between the inlet valve and the check valve, it probably cannot be attended to while the check is open.

Q. "Can a boiler feed-pump be worked without a check valve?

A. "It is possible to work a feed-pump without a check between pump and boiler, but it is not a good plan to try to do so. There should be both a check and cock between boiler and pump. In working a pump without check in pipe, hot water is likely to back up on pump, making trouble in starting it."

Q. How can the size feed-pump required for a boiler be calculated?

A. Allow 1 cubic foot of water per hour per horse power; then get a pump of twice that piston displacement at its ordinary speed; even four times is better, to allow for leaky valves, pipes, etc.

Q. How is the piston displacement calculated?

A. Multiply the plunger diameter in inches by itself and by .7854 to get the area (or look in a table of area of circles). Multiply this area by the stroke in inches; then, if it is a double acting pump, by two. This gives the displacement per stroke (or per double stroke, if it be a double acting pump). Then multiply this by the number of strokes (or double

strokes, as the case may be) per hour. The result will be piston displacement per hour, in cubic inches. Divide this by 1728 for cubic feet, or by 231 for gallons.

Q. How do you cipher up the number of strokes per minute of a single acting pump of a given diameter and stroke, to give a stated number of cubic feet per hour?

A. Divide the cubic feet per hour by 60 to reduce to cubic feet per minute. Multiply the cubic feet per minute by 1728 to reduce to cubic inches per minute. Square the diameter in inches and multiply the product by .7854, to get area of piston in square inches (or get area from a table). Multiply piston area by stroke in inches to get piston displacement per single stroke. Divide this with the cubic inches per minute to get single strokes number of strokes per minute.

Q. In case it was a double acting pump?

A. Half as many strokes.

Q. How would you cipher out the required diameter of a single acting pump

to have a certain number of cubic feet displacement per hour, with given length of strokes and number of strokes per minute?

A. Divide cubic feet per hour by 60 to get cubic feet per minute, multiply by 1728 to get cubic inches per minute. Divide this last by number of single strokes to get displacement per stroke. Divide this by stroke in inches to get plunger area. Divide this plunger area by .7854, and take the square root of the product; or look in a good table of areas of circles and get the diameter corresponding to the area of plunger.

Q. How could you figure out the required length of stroke (single acting) to make a desired piston displacement in cubic feet per hour, the diameter of plunger and the number of strokes per minute being given?

A. Divide cubic feet per hour by 60, and multiply by 1728. Divide by number of strokes per minute and by area of plunger; this last being got either from a table in areas, or by multiplying the square of the diameter by .7854.

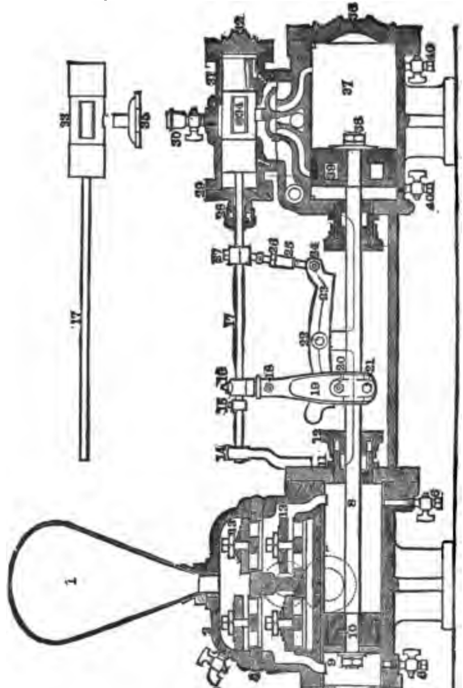


FIG. 110.—CROSS-SECTION OF STEAM PUMP.

INJECTORS.

Q. What is an injector?

A. As the term is ordinarily understood, it applies to a boiler feeding device in which by the impact of a steam jet a current of water is forced, together with the water resulting from the condensation of the steam jet into the boiler which supplied the steam jet.

Q. How many classes of injectors are there?

A. There are lifting and non-lifting; and the former may be divided into those having a separate lifting apparatus delivering to the forcing apparatus, and those in which there is but one set of tubes for both lifting and forcing. Injectors may also be either automatic or adjustable; and they may be simple, or having but one steam jet, one water jet, and one combining tube; or compound, having two or more steam jets or two or more water jets in line, thus acting by successive impacts.

Q. Is it not a sort of paradox for a jet of steam to leave a boiler and return to the same boiler, bringing with it a quantity of water, thus doing the work

of lifting and forcing the water, as well as overcoming the very considerable friction of steam and water in the jets and pipes?

A. Yes, but it can be explained on scientific principles, according to the mechanical theory of heat.

We must first assume that the liquid jet is too cold to be transformed into steam at the atmospheric pressure in its passage through the mixing chamber, else it will be interrupted and steam will escape at the discharge pipe. The water jet must condense all the steam jet, and the mixture be lower than the temperature of corresponding saturation at the mean pressure in the mixing chamber.)This will be 100° C=212° F., if the mixing chamber is open to the air.)

As the steam jet is condensed, water flows in to fill the difference in columns between the steam and the water which it makes. There is then only a jet of liquid to pass on, through the "choke" in the apparatus, into the diverging tube. In this latter water introduced with a given velocity in feet per second would be able to overcome a pressure

due to a height equal to the square of that velocity, divided by twice the rate at which gravity increases the velocity of a falling body at the surface of the earth. This velocity is 32.17 feet per second, so that all we have to do is to properly proportion the jets. Thus, if we have a velocity of 500 feet per second, we should be able to feed against a head of about $500 \div 62.34 = 80 +$ ft., less the head of 33 feet or so due to one atmospheric pressure. The amount of heat and work remain practically unchanged; we get higher velocity by having lower temperature.

Q. As the temperature of the water drafted raises, what is the effect on the proportion conveyed?

A. It is increased.

Q. What is the effect on the velocity of the mixture?

A. It is decreased.

Q. When the temperature of the mixture diminishes, what is the effect on the proportion of conveyed water?

A. It is increased.

Q. At what temperature of the mixture is the proportion of conveyed water least?

A. At 100° C =212° F.

Q. What is the velocity then?

A. The maximum possible.

Q. What is the effect on the water conveyed when the steam is not dry?

A. It is diminished in amount.

Q. Why will not an injector work upon very hot water?

A. Because water that is very hot is more elastic than that which is cold, and will not receive the impact of the jet of steam.

Q. Can you give an example to illustrate the action of impact and speed in driving water into a boiler by a jet of steam from the boiler itself?

A. The firing a tallow candle from a gun through a half open door without smashing the candle or moving the door.

Q. In giving instructions to parties, how to determine the required size of an injector, pump or heater, when the boiler dimensions are known, what rules of thumb are often given to arrive at approximate horse power capacity?

A. For plain cylinder boilers, multiply the diameter by the length, and divide by 6.

For flue boilers, multiply the diameter by the length, and divide by 4.

For multitubular boilers, multiply the square of the diameter by the length, and divide by 4.

All dimensions to be taken in feet and fractions of a foot.

Q. Should an injector be chosen, which is much too large for the desired feeding capacity?

A. No, as these instruments work best at their rated or full capacity. It is best to have two; or an injector and a pump.

Q. Should the interior of an injector be meddled with?

A. No. The important connections of any injector are "Steam," "Suction" and "Feed." In addition to these is the "Overflow," and to the user or operator these are the only parts requiring attention. Any attempts by unskilled persons to interfere with the interior will in nine cases out of ten result in failure and a permanent injury to the machine.

Q. Should injectors be oiled?

A. Injectors should be regularly oiled, the same as any other device in which

there is motion, friction and wear. The oil can be introduced by a suitable oil cup, just as in the cylinder.

Q. Where is the proper place to put an oil cup upon an injector?

A. Upon the steam pipe.

Q. Are injectors as sure as pumps?

A. Injectors have become as safe and sure stationary boiler feeders as pumps; and have this decided advantage in many cases, that they save the power consumed by waste friction of pumps, and also the space required by the latter.

Q. How can the noise of injectors be almost entirely stopped?

A. By the use of a little oil. A small blind oil cup is placed on the top of the injector just back of where the steam enters.

Q. What kind of oil should be used for the purpose?

A. Pure petroleum, having a fire test of 500 or 600 degrees, as crude petroleum contains volatile gases which render the use of it for this purpose dangerous. Only a very small quantity of high test oil need be used, and the effect of it in

the boiler will tend to prevent the deposit of scale.

Q. How much steam pressure needed

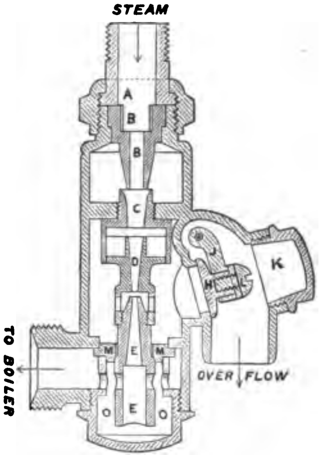


FIG. 111.—PENBERTHY AUTOMATIC INJECTOR.

in an injector for lifts of 5, 10, 15, 20, and 25 feet respectively?

A. About 15, 20, 25, 35, 45 lbs.

Q. How is the Penberthy automatic injector made?

A. A is the tail pipe, B B the steam jet, C the suction tube, D D the combining tube, E the delivery pipe, H the overflow valve, and K the cap of the overflow pipe.

Q. How would you work this?

A. Open the suction valve full; also, the valve in the steam pipe. When water appears at the overflow, gradually close the suction valve. As the steam rises, open the suction valve until the injector takes all the water.

Q. What is the difference between a Hancock Inspirator and an ordinary injector?

A. The inspirator is a double apparatus, one-half of which is a lifter, and the other half a forcer; the lifter drawing the water and delivering it to the forcer, which delivers it to the boiler, at any steam pressure, without adjustment. An ordinary injector is a single apparatus, requiring adjustment for the varying steam pressures.

Q. How high should an inspirator lift water?

A. It should lift water 25 feet, and deliver it into tanks, or to the boiler, as might be desired.

FIG. 112.—HANCOCK INSPIRATOR.

Q. How much steam pressure should be required to lift water 25 feet?

A. 45 pounds.

Q. How hot should it take the water?

A. It should take water of 140° Fah.

on a lift of 3 or 4 feet, or under a head; and on a lift of 25 feet it should take it at from 90° to 100° Fah.

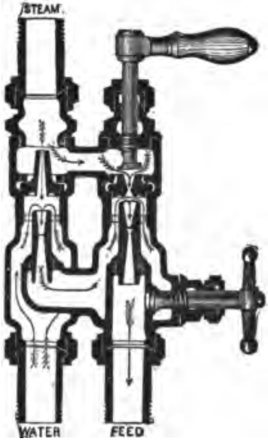


FIG. 113.—LENGTHWISE CENTRAL SECTION OF HANCOCK INSPIRATOR.

Q. How should it deliver the water to the boiler?

A. The temperature should be increased nearly 100 degrees.

Q. In what does the "Unique" injector, shown in Fig. 114, differ from the Hancock inspirator shown in Fig. 113?

A. It is a single tube device with fewer valves.

Q. What advantage is there with this apparatus in case it gets glued up with dirt or chips?

A. It can be cleaned without disturbing the tubes.

Q. How do you start the non-lifting "Unique" injector?

A. Have the overflow open, then open the water valve full, then the steam full and then close the overflow.

Q. How do you stop it?

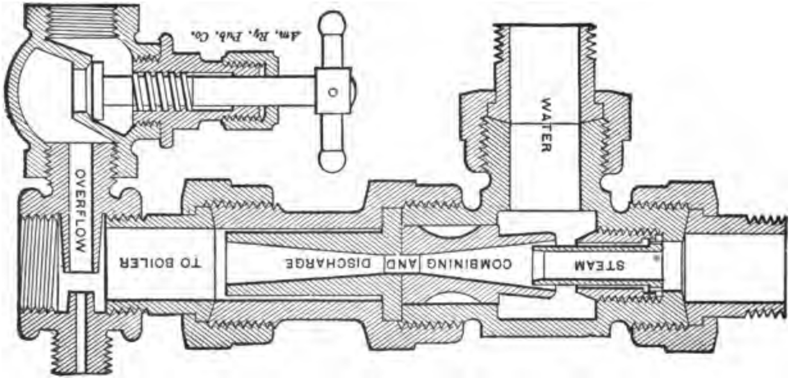
A. Shut off the steam and water, then open the overflow.

Q. How do you start a lifting injector of the "Unique" type?

A. Having the overflow open, open the jet, and when water shows at the overflow open the steam valve; then shut the jet and the overflow.

Q. How do you stop it?

A. Shut off the steam and open the overflow.



THE "UNIQUE" INJECTOR.

NON CONDUCTING COVERINGS.

Q. What is the object of "boiler coverings?"

A. To prevent or lessen loss of heat, and consequently loss of temperature and pressure of steam.

Q. Name some of the non-conducting materials used to prevent radiation from exposed boiler surfaces?

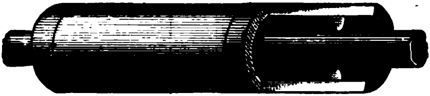


FIG. 114.—GILMOUR'S NON-CONDUCTING BOILER COVERING.

A. Wool, hair, wool felt, hair felt, wood, cork, wood saw dust, paper pulp, and wool shoddy pulp, mineral wool and rock wool, "fossil meal" or infusorial earth, ashes, plaster of Paris, asbestos fiber, and dead air spaces.

Q. Which are the best?

A. Those which have the greatest proportion of air space in them.

Q. What else is required of a non-

FIG. 115.—GILMOUR'S SECTIONAL PLASTER COVERING.

FIG. 116.—GILMOUR'S SECTIONAL MINERAL WOOL COVERING.

conducting covering, besides poor heat conducting qualities?

A. That it shall be uninjured by high temperatures; shall not crack and fall off; shall not be too heavy for pipes; shall not be affected by leaks from within or without; shall not corrode the metal, and shall be easily applied and removed for inspections of the surfaces below it. It is of course desirable that it be sightly, and cheap in first cost and in application.

Q. Do you consider a non-conducting covering indispensable?

A. By all means; even on locomotive fire-boxes.

COMBUSTION.

Q. What is combustion?

A. Familiarly defined, "burning." Chemically speaking, the union of two unlike substances to form a third, and attended with the production of heat and light. This last definition is ordinarily limited so as to make oxygen always one of the substances.

Q. What is oxygen?

A. One of the two gases which in

mechanical mixture constitute the air we breathe.

Q. Of what is oxygen composed?

A. It is not composed of anything but just oxygen. It is a simple substance; a chemical element.

Q. With what is oxygen mixed in the air; in what proportion?

A. With another simple element, nitrogen gas, in the proportion of 79 volumes of nitrogen to 21 of oxygen.

Q. Anything else in air besides oxygen and nitrogen?

A. A trifle of vapor of water, and an almost imperceptible trace of carbonic acid gas.

Q How much does a cubic foot of air weigh?

A. At 32° Fahr., 0.080728 lb. advoirdupois, or 565.1 grains; at 62° F., 076097 lb. or 532.7 grains. The warmer the lighter.

Q. What is the volume of one lb. of air?

A. At 32° F., and at ordinary atmospheric pressure of 14.7 lbs. per square inch, 12.4 cubic ft

Q. Does nitrogen support combus-

tion; that is, can anything burn in it?

A. No.

Q. What are its properties?

A. Mostly negative. It will not burn nor let anything burn in it; nor support life; has no smell, taste, nor color; does not dissolve in water; is neither acid nor alkali.

Q. What is the use of the nitrogen in the air?

A. To keep combustible things from burning up at once, and animals from living out their lives at once at a lightning rate of speed, as would be the case if the air was pure oxygen.

Q. Where do we find oxygen besides mixed with nitrogen in the air?

A. It is chemically combined so as to form about 8-9 of water, and about one-half of silicia, chalk and alumina, which three last named are the most plentiful components of the earth's crust.

Q. What is the "law of definite proportions" in chemical combination?

A. "In any chemical compound the nature and the proportions of its constituents are fixed, definite and measurable." Thus in 100 lbs. of water, there are 88.9

lbs. of oxygen and 11.1 of hydrogen: no more nor no less of either.

Q. How many compounds of carbon and oxygen are there?

A. Two; carbonic oxide or imperfectly burned carbon (CO), and carbonic acid or perfectly burned carbon (CO_2)

		Parts by Weight.	
	Symbol.	Carbon.	Oxygen.
Carbonic Oxide,	CO	12	16
Carbonic Acid,	CO_2	12	32

Q. Can not these proportions be represented more conveniently?

A. Yes; as follows:

	Percentages.	
	Carbon.	Oxygen.
Carbonic Oxide,	42.86	57.14
Carbonic Acid,	27.27	72.73

Q. What conditions are necessary to the combustion of carbon and hydrogen?

A. That the carbon and oxygen must be in contact, and at a temperature sufficiently high to start the combustion.

Q. What is ordinary flame?

A. Gas or vapor the surface of which is burning or emitting light.

Q. What color has the flame of hydrogen?

A. It is very pale blue; almost colorless.

Q. What is the color of carbonic oxide flame?

A. Bluish, as seen when anthracite or coke is burning.

Q. What is the specific heat of a substance?

A. The quantity of heat required to raise 1 lb. of it 1° F., as some substances have more capacity for heat than others.

Q. What is the unit of measurement of specific heat?

A. The amount of heat required to raise 1 lb. of water 1° F., under certain conditions not necessary to specify here.

Q. What is the specific heat of carbonic acid?

A. 0.2164.

Q. And of nitrogen?

A. 0 244.

Q. With these data, how can you cipher out the quantity of heat required to raise 1° F. the products of complete combustion of 1 lb. of carbon?

A. The following is the calculation:—

Products.	Lbs.	Specific Heat.	Heat Units.
Carbonic acid,	3.67 ×	.2164	.794
Nitrogen,	8.94 ×	.244	2.181
		Total,	2.975

Q. How many heat units in the complete combustion of 1 lb. of carbon?

A. 14,544.

Q. Then what is the highest theoretiical temperature you can get by completely burning 1 lb. of carbon?

A. 14544 divided by 2975=4889° Fahr.

Q. Suppose we allowed 18 lbs. of air to burn 1 lb. of carbon instead of 1161, as we have just been figuring on, how would you cipher out the temperature of the gaseous products?

A. The gases would then contain as before

Carbon	1. lb.
Oxygen	2.67
Nitrogen	8.94
plus unconsumed air.	6.39
Total	19.

And the heat units would be got thus:—

Carbonic acid	3.67	× .2164	= .794
Nitrogen	8.94	× .244	= 2.181
Air	6.39	× .2377*	= 1.519
	19.00		4.494

14.544 ÷ 4.494 = 3236°F.

Q. What should this teach us?

A. The uneconomical effect of introducing too great a quantity air in the furnace.

Q. On what does the temperature of combustion depend?

A. On the kind of coal and the kind and the quantity of products of combustion, including the air required to burn the fuel.

Q. When coal is burned, what are the principal gaseous products?

A. Carbonic oxide, carbonic acid, nitrogen, unconsumed air, and gaseous steam.

Q. How much carbonic acid (CO_2) ought 1 lb. of carbon to make?

A. It should take 2.67 lbs. of oxygen,

*Specific heat of air.

and make 3.67 lbs. of carbonic acid (CO_2).

Q. How much nitrogen would that set free from the air?

A. 8.94 lbs.

Q. When coal is shovelled upon the grate bars and ignited, what happens first?

A. The two constituents of the coal, the carbon and hydrogen are separated, and as a matter of fact, a gas works is made.

Q. Will carbon burn by itself?

A. No; no more than a stone will.

Q. What is necessary in order to have perfect combustion?

A. Time, space, air and heat.

Q. What is smoke?

A. "The exhalation, visible vapor, or substance that escapes or is expelled from a burning body; applied especially to the volatile matter expelled from vegetable matter, or wood, coal, peat and the like; the matter expelled from metallic substances being more generally called *fume* or *fumes*."— *Webster*.

Q. Can smoke be burned?

A. Yes, by giving it oxygen enough

to cause it to futher oxydize; that is, for the unburned carbon to burn, and for the partly burned carbon to complete its oxidization.

Q. What is the disadvantage of admitting air back of the bridge wall in burning soft coal?

A. Impedes the draft.

Q. How high a temperature may be got by burning pure hydrogen gas, in pure air?

A. When one pound of hydrogen burns in air, we get as product gaseous steam (which has a specific heat of .475), and nitrogen (which has a specific heat of .244). It takes 34.8 lbs of air, containing 8 lbs. of oxygen and 26.8 lbs. of nitrogen. Then the heat units absorbed per degree of rise of temperature by the gases from 1 lb. of burned hydrogen are as follows:

		Heat units
Gaseous steam	9 x .475 =	4.275
Nitrogen	26.8 x .244 =	6.539
	35.8	10.814

As the total heat of combustion of

one pound of hydrogen is 62,032 units the temperature of combustion would be $62.032 \div 10.814 = 5{,}744°$ F.

Q. How can you find out how many cubic feet of gases of combustion go out of your furnace, supposing that you have an analysis of the coal?

A. To find the volume at 62° F. of the gaseous products of combustion of one pound of combustible completely burned:

Multiply the weight of each gaseous product (carbonic acid, steam, sulphurous acid and nitrogen) by the volume of one pound in cubic feet at 62° F., as per proper tables, as follows:

1 lb. carbonic acid equals	8.594	cub.	feet.
1 lb. steam	21.125	"	"
1 lb. sulphurous acid	5.848	"	"
1 lb. nitrogen	13.501	"	"

As the relative weights of the various gaseous products are as follows:

Carbonic acid	3.66	times	carbon.
Steam	9	"	hydrogen.
Sulphurous acid	2	"	sulphur.
Nitrogen	8.86	"	carbon.
	26.8	"	hydrogen.
	9.35	"	sulphur.

we get the following:

.0366x8.59 .315 times the volume of carbon, equal volume of carbonic acid.
.09x190=1.9 times the volume of the hydrogen, equal volume of the steam.
.02x5.85=.117 times the volume of the sulphur, equal volume of the sulphurous acid.

Then :—

.0893x13.5=1.206	times	the	volume	of the	carbon.
.268x13.5=3 618	"	"	"	"	hydrogen.
.033.x13.5=0.45	"	"	"	"	sulphur.
.01x13.5=.135	"	"	"	"	nitrogen.

is equal to the volume of the nitrogen. Then,

1.52 x	the	total	weight of	carbon or	equals total volume of gases of combustion.
5.52 x	"	"	"	hydrogen,	
.567 x	"	"	"	sulphur,	
.135 x	"	"	"	nitrogen,	

Thus : Suppose we have a combustible having the following analysis :

Carbon	.86
Hydrogen	.68
Nitrogen	.01
Sulphur	.05
Total	1.00

(Ash and oxygen are not considered, the percentages being those of the combustible part).

With such a combustible the volume at 62° F. of the gaseous products will be as follows :

.86x1.52=1.3072 by reason of the carbon.
.08x5.52=4.416 " " " hydrogen.
.01x.567= .0057 " " " sulphur.
.05x 1.35= .0068 " " " nitrogen.

Total volume 5.7327 per pound of combustible.

Knowing the quantity of ash and of oxygen in the fuel, the quantity of combustible can readily be got.

The volume at any other temperature may be got by dividing 523.2 into the absolute temperature* and using that as a multiplier for the volume at 62° F.

Q. Can you give any idea of the quantity of air actually used to effect combustion, as compared with the theoretical amount?

A. "With chimney draft, the experiments of the U. S. Navy show that ordinary furnaces require about twice the theoretical amount of air to secure perfect combustion.

"Prof. Schwackhoffer, of Vienna, found in the boilers used in Europe an average excess of 70 per cent. of the total amount passing through the fire—or that over three times the theoretical amount was used.

*Themometer reading, plus 461.2 degrees.

"A series of 12 tests made by same with artificial blast, gave an average excess of only 22 per cent. of the whole quantity, and in a few cases none at all, with only traces of carbonic oxide, showing perfect combustion."—*Babcock & Wilcox.*

"A series of analyses by Dr. Behr of the escaping gases from a Babcock & Wilcox boiler, with chimney draft, showed an average excess of air equal to 48 per cent. of the whole quantity.

Q. How would you determine the temperature of a fire from its color?

A. The following table, from M. Pouillet, will enable the temperature to be judged by the appearance of the fire:

Appearance.	Temp. Fahr.	Appearance.	Temp. Fahr.
Red, just visible ...	[illegible]77°	Orange, deep......	2010
" dull........ ...	1290	" clear.....	21[illegible]0
" Cherry, dull.	14[illegible]0	White heat....... .	2370
" " full..	1650	" bright......	2550
" " clear	18[illegible]0	" dazzling...	2730

Q. How would you tell it from the melting points of various metals, alloys, and other substances?

A. By reference to this table:

Substance:	Temp. Fah.
Tallow	92°
Spermaceti	120
Wax, white	154
Sulphur	239
Tin	455
Metal:	
Bismuth	518
Lead	603
Zinc	739
Antimony	801
Brass	1650
Silver, pure	1830
Gold Coin	2156
Iron Cast, medium	2010
Steel	2550
Wrought Iron	2910

FUELS.

Q. What is fuel?

A. Anything that can be economically burned in air to produce heat.

Q. On what does the economic value of a fuel depend?

A. On its heating power.

Q. What gives fuel its heating power?

A. Carbon and hydrogen.

Q. What is carbon?

A. An elementary substance, which exists in these forms, like charcoal, graphite (black lead, plumbago), and the diamond.

Q. What is hydrogen?

A. A colorless, odorless, tasteless gas, the light test of the elementary substances in chemistry. It will not support life or ordinary combustion ; burns with oxygen, forming water.

Q. What are the principal fuels used under steam boilers?

A. Wood, charcoal, peat, hard coal, soft coal, coke and gas.

Q. How may fuels be classified?

A. As follows :

I. Wood.		
II. Peat.		
III. Coal,	*a.* Lignite,	Non caking, rich in oxygen.
	b. Bituminous,	Caking
	c. Anthracite,	Non caking, rich in carbon.
IV. Products of carbonisation or incomplete burning.	*a.* Solid,	Wood-charcoal, Peat-charcoal. Coke.
	b. Volatile,	Carbonic oxide. Hydrogen. Hydro-carbons.

Q. How much moisture in freshly cut green wood?

A. About 45 per cent.

Q. How much is left when it is as dry as it generally gets?

A. 18 to 20 per cent.

Q. What is peat?

A. It is made of various plants which

are gradually uniting with oxygen, under moist influences. It contains about 75 per cent. of water.

Q. What is lignite?

A. Half formed coal; between peat and bituminous coal.

Q. Is it the same as brown coal?

A. Not quite.

Q. How much water in lignite?

A. 10 to 20 per cent.

Q. How much bitumen in American bituminous coals?

A. None.

Q. Then what is meant by a bituminous coal?

A. Those which have a large proportion of organic (that is, in this case vegetably formed) matter in addition to carbon.

Q. About what is the composition of bituminous coals?

A. They will range about as follows:

Carbon	75	to	80	per cent.
Hydrogen	5	to	6	" "
Nitrogen	1	to	2	" "
Oxygen	4	to	10	" "
Sulphur	0.4	to	3	" "
Ash	3	to	10	" "

Q. What is the distinguishing feature of bituminous coal?

A. 18 to 50 per cent. of volatile combustible matter.

Q. What is a caking coal?

A. One which melts down and swells up, getting pasty in the fire, and caking together on the grate.

Q. What is a non-caking coal?

A. One which does not get pasty and cake together in the grate, but burns more like charcoal. Block coal is of this type.

Q. What is free burning coal?

A. The same as non-caking coal.

Q. What is coke?

A. What is left when gas coal has the gas distilled out of it; a hard, gray, steely, lustrous substance; burning well under a strong draft

Q. What is semi-bituminous coal?

A. Softer and with less volatile matter than bituminous; kindling readily, free from smoke and soot, and easily regulated.

Q. What is semi-anthracite?

A. It has 7 to 8 per cent. of volatile matter, part of which is in cells or clefts;

kindles freely. The Wilkesbarre coal is of this kind.

Q. What are the characteristics of true anthracite?

A. It is a hard, slow kindling, poor heat conductor, burns at a high temperature, radiates very strongly, is hard to quench, and gives off no water in burning.

Q. What are its advantages?

A. Great heating power, density, freedom from swelling in the furnace, and exemption from deterioration when exposed to the weather.

Q. What can you say about the value of "slack" as a fuel under steam boilers?

A. "Slack" or the screenings from coal, when properly mixed—anthracite and bituminous,—and burned by means of a blower on a grate adapted to it, is nearly equal in value of combustible to coal, but its percentage of refuse is greater.

Q. What is the best kind of wood for fuel?

A. The effective value of all kinds of wood *per pound*, when dry, is substan-

tially the same. The following are the weights and comparative value of different woods by the cord:

Kind of Wood.	Wght	Kind of Wood.	Wght
Hickory, shell bark	4469	Southern Pine	3375
" red heart.	3705	Virginia "	2680
White Oak...	3821	Spruce..............	2325
Red Oak...........	3254	New Jersey Pine	2137
Beech	3126	Yellow Pine.......	1904
Hard Maple........	2878	White "	1868

Q. What is the action upon the boiler sheets, of coal containing sulphur?

A. Very detrimental.

Q. What about storing bituminous coals in a dry climate?

A. They should be kept from the sun, or they will lose their hardness and value; will get softer.

Q. Does anthracite coal spoil by being left in the sun in a dry climate?

A. No. There has been hard coal piled upon the beach at St. Paul de Londa for twenty years without losing its worth.

Q. Does wetting coal improve it or not for the purpose of making steam?

A. Recent experiments tend to show that it causes a loss.

Q. How many pounds of dry ashes should there be remaining after the burning of one gross ton (2240 pounds) of good hard coal?

A. As good anthracite runs about 7 per cent., of ash that would make a minimum of $2240 \times .07 = 156.8$ lbs.

Q. How many cubic feet of space should you have in your coal-bunker for each gross ton of hard coal to be stored?

A. As anthracite runs about 94 lbs. to the cubic foot, that would make about $2240 \div 94 = 23.83$ cubic feet.

Q. How big a cube would that make?

A. 2.88 ft. = 34.56 inches on a side.

Q. Show how the relative value of various coals is estimated from the money point of view?

A. The Philadelphia Water-Works made tests of the relative values pea, egg, and soft coal for steam purposes. The tests which were made at Belmont pumping-station extended over 48 hours, and were remarkably uniform in the conditions. Hard pea coal did 35.8 per cent., more work than the egg for a dol-

lar, soft coal 26.6 per cent., and dusty pea coal 49.4 per cent. more. Soft coal showed the highest "duty" and the "egg" coal came next; but the price told the story. For clean pea $2.30, egg $4.38, soft coal $3.58, dusty pea $2.65, were the relative costs in that case of the different kinds, for a unit of work.

Q. Can you give some figures showing the results of tests made with different kinds of coal in standard locomotive boilers?

A. Dr. Cresson found for anthracite 50 per cent. of the total heat obtainable; bituminous 54; semi-bituminous, 55.2.

Q. Are there any figures showing the results of tests with coal slack or waste?

A. Dr. Cresson found for anthracite waste, 69.4 per cent.; marketable anthracite, 65.5; bituminous waste, 64.3; bituminous lump, 68.3. These tests were with the Wootten boiler.

Q. Can you quote a table giving the qualities of American coals as regards ash and heating power?

A. The following table of American coals has been compiled from various sources by Babcock & Wilcox:

AMERICAN COALS.

COAL. STATE.	KIND OF COAL.	Per cent. of ash.	Theoretical Value. In Heat Units.	Theoretical Value. In Pounds of water evap.
Penn	....Anthracite	3.49	14,199	14.70
"	.... "	6.13	1[illegible],585	14.01
"	.... "	2.90	14,221	14 70
"	... Cannel	15.02	13,143	13.60
"	..Connellsville	6 50	13,368	13.84
"	Semi-bit'inous	10.77	13,155	13.62
"	. .Stone's Gas	5.00	14,021	14.51
"	Youghiogheny	5.00	14,265	14.76
"	.........Brown	9.50	12,324	12.75
Kentucky	....Caking	2.75	14,3[illegible]1	14.89
"	.. Cannel	2.00	15,193	16.76
"	.... "	14 80	13,260	13.84
"	....Lignite	7.00	9,326	9 65
Ill.	.....Bureau Co	5.20	13,025	13.48
"	.... Mercer Co	5.60	13,123	13.58
"	.. ..Montauk	5.50	12,659	13.10
Ind	...........Block	2.50	13,583	14 38
"	. ...Caking	5.66	14,146	14.64
"	.... .Cannel	6.00	13,097	13 56
Md	.. .Cumberland	13.98	12,226	12.65
Ark	....Lignite	5.00	9 215	9.54
Col	.... "	9.25	13,562	14.04
"	.... "	4.50	13,866	14 35
Texas	.... "	4.50	13,262	13.41
Wash. Ter	... "	3.40	11,551	11 96
Penn	.. ..Petroleum		20,746	21.47

FIRING.

Q. What should be required of a fireman?

A. That he should know his duties and be watchful, reliable, neat, sober, careful, and desirous of learning each day something new.

Q. What about rapidity of combustion in starting up a fire?

A. The fire should not be allowed to be too brisk in starting up, when the boiler is cold.

Q. In getting up steam for the first time, what fuel is best, and why?

A. Wood, because it is more easily regulated than coal or coke.

Q. How long should you take to get up steam for the first time upon the ordinary return tubular boiler 5′x16′?

A. About 3 to 4 hours.

Q. What should the fireman be doing in the mean time?

A. Inspecting every joint and seam that is visible.

Q. After steam is got up for the first time what should be done?

A. The boiler should be allowed to stand for about an hour under full pressure; then the surface blow should be opened to blow out any oil or light dirt that might have been present.

Q. In kindling a fire, where should most of the shavings be put?

A. In front (speaking of a stationary or a marine boiler).

Q. How should a shavings fire be started?

A. Throw a few shovels full into the furnace, upon part of the grate only; then light this, close the dampers and check the draught, until the boiler begins to send off air from the water; discharge this air through the upper gauge cock which should be left open for that purpose.

Q. What should be seen to after the fire is started?

A. When the steam pressure commences to rise it should be seen that there are no leaks, and that all the cocks and valves move easily.

Q. Is it best to fire slowly or quickly in starting up?

A. "Little and often" is the best motto.

Q. What is the sign of proper combustion?

A. A bright flame all over the grate alike.

Q. What are signs of bad combustion?

A. Blue flame, dark spots and visible smoke.

Q. Is it possible to avoid the emission of dark visible smoke just after firing?

A. With some fuels it can be avoided.

Q. What about the thickness of the fire?

A. Evenness is of more importance than its actual thickness; for the draft is regulated to the actual thickness.

Q. What about bare spots?

A. They should never be allowed to remain uncovered, as they let cold air in.

Q. Is a red flame a sign of good or bad combustion?

A. Of bad; the darker the red the more incomplete the combustion.

Q. Should a boiler be fired with a perfectly level surface of fuel?

A. No, it is better to have it saucer shaped, more particularly for the purpose of preventing cold air from coming up at the edges, right upon the hot sheets.

Q. What difference in the way of cover-

ing the fire with anthracite and with bituminous coal?

A. In firing anthracite, you must scatter the coal over very thinly and evenly; with bituminous you must cover small local portions at each shovel full. Anthracite should be of uniform size, fired often and in small quantities and carried as light as possible. The furnace door should be kept open as little as possible. With bituminous these items are not necessary.

Q. In firing with wood, what should be observed?

A. The wood should be laid in an orderly manner, and not just piled up "helter-skelter." (This is especially the case with four-foot cord wood).

Q Should wet wood be burned?

A. Not if dry can be had.

Q. What kind of wood especially r - quire to be dry in burning?

A. The light woods like cedar, white pine, spruce, hemlock, etc.

Q. Is black oak a good fuel?

A. No; takes too much draught.

Q. Does it hurt a good fire to disturb it?

A. No.

Q. Why does it hurt a fire of anthracite coal to disturb it?

A. Because the ashes and clinkers being brought up to the top, act as a damper.

Q. In firing with shavings should the fire box be kept full, or not?

A. It should.

Q. What is the danger in firing heavily with shavings?

A. Blowing back, by reason of the grates getting clogged.

Q. What is the best kind of wood fuel to use in connection with coal to force things?

A. Barrel staves, especially if of whiskey, resin, or oil barrels.

Q. Suppose you have to use wood with coal, to help it along, is it better to put it upon the coal or under it?

A. It is better to force it under.

Q. What about firing with two furnaces?

A. They should be alternately fired.

Q. What about entirely closing the chimney damper?

A. It should never be entirely closed

when there is fire upon the grate, lest explosions take place in the flues.

Q. What precaution should be taken with regard to the furnace door in cleaning or firing?

A. It should be kept open as little as possible, as when open, the cold air chills the inside of the boiler.

Q. Should the draft be changed while firing?

A. It may be lessened, by closing the lower door; not by touching the chimney damper.

Q. What is the effect of stirring the fire?

A. Bad, as it causes the fuel to drop through the grate without being burned. (This of course does not mean that a soft coal fire should not be broken up).

Q. Is it desirable to have the fuel wet?

A. Soft coal should be dry.

Q. What is the effect of wetting soft coal?

A. To stick up the sides of the flues with pitchy soot, which will catch dry particles and clog up the flues.

Q. How about hard coal being dry or damp?

A. It is sometimes better to dampen it, in order to make it burn more freely and not crowd.

Q. Does coke require any different ratio between heating and grate surfaces than coal?

A. It needs more grate, and hence less proportionate heating surface.

Q. Does coke require thick or thin bed?

A. Thick.

Q. Should you burn more or less weight of coke per hour per square foot of grate, than of coal?

A. Less, by about one-third.

Q. Should coke fired boilers have the fire in front of the boiler or underneath?

A. Underneath.

Q. Does coke require as long flues as coal?

A. No.

Q. Which takes a thicker fire, hard or soft coal?

A. Soft.

Q. How about the thickness of a peat fire?

A. It should be very thick.

Q. How about the thickness of a coke fire?

A. It should be thicker than that of any other fuel.

Q. How about wood?

A. It should be burned in a very heavy fire.

Q. Which needs more air, coke or coal?

A. Coke, by about one-third.

Q. In firing with coal is there generally too much or too little air at first?

A. Too little.

Q. How is it with coke?

A. Too little.

Q. How could the demand for more air at the time of coaling be met?

A. By having an automatic valve in the face of the door, which should open when the door is opened for coaling, and close gradually in a given time, as the coal required less and less air.

Q. Will a dumping ash pan for a locomotive boiler furnace save coal?

A. Only by keeping the fires clean.

Q. What is probably the principal advantage of the brick arch in locomotive fire boxes?

A. It compels the fireman to fire right.

Q. Should you put fuel on while the feed is on?

A. No; unless you feed all the time, in which case it makes little or no difference.

Q. What can be done to cure down draught in a stack?

A. Put at its top a deflector composed of a number of conical rings so that the stronger the wind blows the more the gases are drawn up.

CLEANING FIRES.

Q. Before cleaning the fire, what should be done?

A. The damper should be opened to let the gases and dust pass into the flue.

Q. What should be done about cleaning if there are more than two furnaces?

A. They should be cleaned alternately.

Q. How should a large furnace be cleaned?

A. One-half at a time.

Q. What is necessary as regards feed before the fire is cleaned?

A. That there be an extra quantity of water in it, and a full head of steam?

Q. Should cleaning be done with a full fire or with a low one?

A. With a full one, to prevent loss of

fuel by lowering the temperature of the furnace.

Q. Should you clean with a good fire or a poor one?

A. With a good one; the furnace door having been opened for a minute to take the white glare off it.

Q. What should be done with the live fire in cleaning?

A. It should be pushed back to the bridge without disturbing any of the ashes or cinders.

Q. When this is done what next?

A. The ashes and cinders in front should be removed, and then the proceeding reversed, drawing the live fire front, and taking out the cinders at the back.

Q. What next?

A. The fire evenly spread, and what ashes and cinders remain picked out, and a thin layer of fresh coal put on.

Q. When is the time to clean?

A. Only when there is no white light shines through the grate into the ash pit.

Q. Is it always necessary to clean when there is no white light shines through the grate to the ash pit?

A. No; it is better sometimes, especially with anthracite, to clean from below with a thin hooked poker.

Q. How about the necessity of cleaning a fire of bituminous coal?

A. It should be broken up often to let the air get through. It should then be pushed back towards the bridge, and a smail amount added in front and allowed to coke.

Q. Suppose the fire has been let get low or the grate uncovered, what should be done?

A. There should be put upon the bare places some waste, wood, or other light substance, then some coal thrown on, and the damper opened out.

Q. What should *not* be done?

A. The thin part should not be poked, as that might put it out.

Q. When is the best time to remove clinkers from the fire-bricks of a furnace, so as to do the least damage to the walls?

A. Just after hauling fires, while the clinkers are hot and soft.

Q. What will lessen the formation of clinkers with hard coal?

A. Oyster shells mixed in small proportion with the coal.

HOT BLAST AND FORCED DRAFT.

Q. What is the essential feature in some patent furnaces?

A. The use of a hollow bridge wall and back to the furnace, as well as hollow side walls, to heat the air which is admitted at the side of the grates and at the top of the bridge wall.

Q. What is the principal feature in other patent furnaces?

A. The waste heat from the chimney is used to furnish a hot blast to the furnace; with a setting that tends to distribute the heated products of combustion evenly over the surface of the boiler. There is a hollow mid-wall running lengthwise of the furnace, and admitting air over the grate. Air is forced in by an injector.

Q. What is the advantage of lining the furnace of a locomotive boiler with fire bricks?

A. In order that it shall be intensely hot when the air enters, and so cause instant and complete combustion.

Q. Where may a forced blast be applied?

A. Either above or beyond the grate as an exhaust, or under it as a pressure.

Q. Which is better, blast above the grate or below it?

A. Below.

Q. What is often gained by the use of forced blast?

A. The ability to burn poorer fuel and use a lower chimney.

Q. What is the disadvantage of a fan blower for a forced blast?

A. It requires special machinery to drive it.

Q. What is the disadvantage of a jet apparatus for forced blast?

A. You must have steam up before you can get your extra draft, and in many places it makes too much noise.

Q. Can you describe a boiler setting in which the air supply is heated before passing through the grate?

A. In the one shown, Fig. 123, there is a lining of fire brick upon all sides and over the bridge wall, precisely as in the old style. But the bridge wall is hollow and contains a flue that is covered with

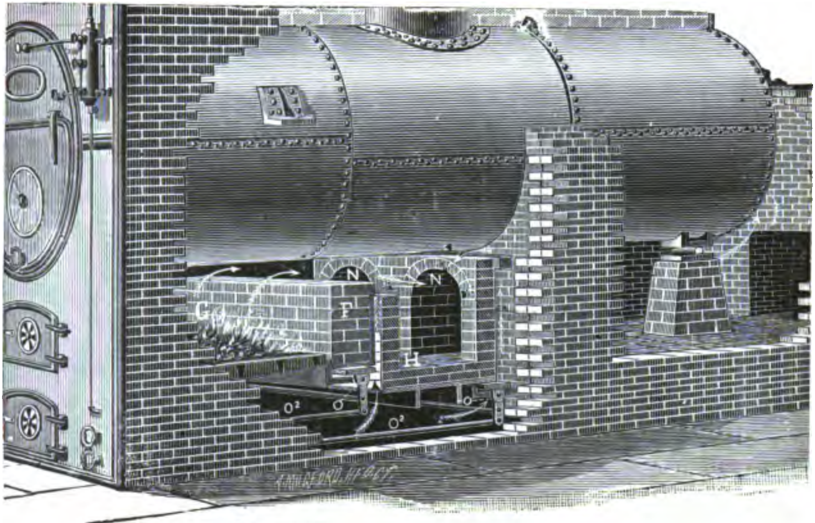


FIG. 117.—THE LOWE BOILER FURNACE.

a gate at the bottom by which the supply of air flowing into the main flue or combustion chamber may be regulated. Back of the regular bridge wall there is another wall, lined with firebrick, that is built up close against the boiler, and which has two arched passages through it leading to the flue beyond. This wall is also hollow and contains a flue covered with a gate similar to the one in the bridge wall. This flue rises to the top of the wall and has an opening at that point into the combustion chamber.

The gases in passing through the combustion chamber on their way to the arches in the back wall are supplemented by two streams of hot air entering above and below. This tends toward a perfect mixing of the oxygen with the combustible gases; and the lining of firebrick, which should be at all times very highly heated, should insure their certain ignition.

The remainder of the setting possesses no peculiar features. The back flue is somewhat shorter than where the combustion chamber is not used. The arch

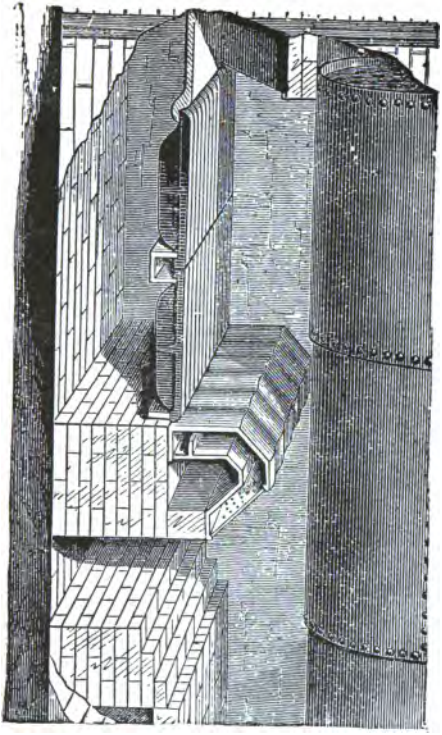


Fig. 118.—McMurray Bridge Wall.

or flue plates may be constructed of any style and pattern to suit the user. The boiler may be supported upon a stand with an expansion plate, as here shown, or may be held by the side brackets.

Q. What is the nature of the McMurray setting?

A. There is a corrugated hollow bridge wall which admits air behind it, having previously heated it by the impinging flames. Its construction is shown in Fig. 118.

FLUE CLEANERS.

Q. Are flue cleaners useful?

A. Flue cleaners are now so handy and inexpensive that there is absolutely no excuse for any one letting the heating surface of his flues and tubes remain covered with a non-conducting deposit, which not only lessens the steaming capacity and the economy of the boiler, but actually corrodes the metal.

Q. What are the principal kinds?

A. Scrapers, brushes, straight steam jets, revolving or spiral steam jets.

Q. Describe a simple flue scraper?

A. There are three flat steel springs, each carrying a crescent shaped scrap-

FIG. 119.—CLEVELAND STEAM FLUE CLEANER

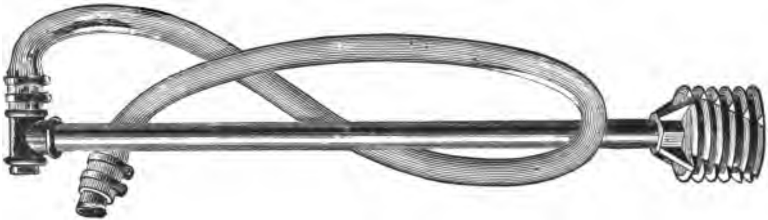


FIG. 120.—VAN DUZEN'S STEAM FLUE CLEANER.

ing blade, parallel with the length of the tube, and also one at right angles therewith, so that the edges of the scraping blades act when the tool is revolved or twisted as well as when it is pulled lengthwise through the tubes.

Q. Describe a simple form of steam auger?

A. In the "Cleveland" steam flue cleaner there is simply a nozzle, on the

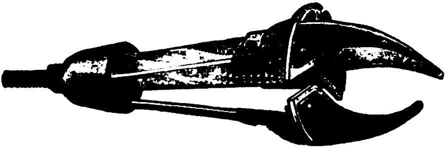


FIG. 121.—"CRESCENT" FLUE-SCRAPER.

end of a handle of suitable length, and supplied with high pressure steam by a steam hose. The nozzle has a conical end, to fit and fill the ends of tubes of various sizes, and the steam is given a spiral or twirling direction by spiral ribs within the nozzle.

Q Can you show any other kind?

A. In the "Crescent," there is also a handle, a steam hose, and a conical noz-

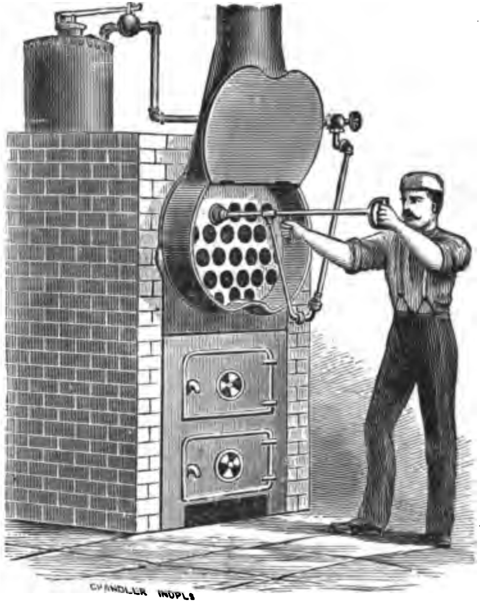


FIG. 122.—MANNER OF USING A STEAM FLUE CLEANER.

zle; but the spiral motion is given to the steam jet by having it escape through an S-shaped slit, having suitably inclined edges in the end of the cone.

CORROSION AND INCRUSTATION

Q. What is corrosion?

A. The eating of the boiler sheets so as to lessen their strength; generally similar to ordinary rusting.

Q. What is incrustation?

A. The deposit of a hard, stony coating on the bottoms and sides of the shell and tubes.

Q. What are the evil effects of incrustation?

A. Reduction of capacity, over-heating of plates, and prevention of inspection.

Q. Does a soft deposit do harm to a boiler?

A. Yes; it does not settle at once, and it makes circulation more sluggish.

Q. How may a sludge deposit be detected?

A "By leakage at the seams, fractures at the edge of the plates and in the line of rivets, and by over-heating

and consequent depression of portions of the plates where it rests." (J. M. Allen).

Q. What aggravates the trouble from sludge in boiling?

A. Grease.

Q. What is pitting?

A. Eating holes in the sheet, caused by corrosive action on non-homogeneous boiler plates.

Q. What is grooving?

A. A line of corrosion at or near the edge of a lap joint or a welt.

Q. What is "bleeding?"

A. Exudation of reddish water from the seams of a boiler.

Q. How may pitting be cured?

A Pitting can, according to the recent report of the Committee on Boilers to the Railway Master Mechanics' Association, be stopped and the plate brought into a healthy condition by scraping the affected spots and cleaning the surface with a strong solution of soda or petroleum, to remove any grease or acidity, and then coating with a thin wash of Portland cement. Even so simple an expedient as filling the cleaned

pit-holes with red lead has, in marine practice, proved quite effectual in preventing any further waste.

Q. What is the danger of neglecting to keep the boiler clean?

A. Burning or blistering the portions which are covered with scale, and consequent increased liability to explosion under working conditions.

Q. Suppose that the feed water contains 20 grains of incrusting material per gallon; how much would that make per month in a locomotive taking 45 gallons per mile and running 2000 miles a month?

A. $20 \times 45 \times 2000 \div 7000 = 257$ lbs.

Q. What precautions should be taken with scaling tools?

A. They should not have sharp edges, and care should be taken not to dent or cut the plates, rivets, stays, or braces.

Q. How can you scale off horizontal tubes?

A. By running a scaling bar between them; or by removing some in order to get at the rest.

Q. What should be the order of doing as regards braces?

A. They should have the loose scale knocked from them.

Q. How should washing down be done?

A. Commence in the steam spaces, and give the steam drnm (if there is one) and the back connections special attention. Then take the hose to each man-hole and wash down the furnace crowns; then get into the mud holes at the bottom. Then hoe out the dirt, swab all over, and leave the boiler open until it is dry—which may be facilitated by pans of burning charcoal.

Q. How may marine boilers which are placed athwartships be cleaned out more readily?

A. By listing the vessel so the slush and water will run out at the front of the boilers, and removing some of the fire room floor plates so the water and dirt will run into the bilge.

Q. Should "doses" of anti-incrustators be given "little and often," or in large quantities?

A. Little and often.

Q. Should the fire be drawn once a week and the entire boiler blown off?

A. No; that bakes on the sludge.

Q. What can you say about the effect on the plates?

A. The sudden cooling tends to crack them.

Q. How should a boiler be blown off and cleaned out?

A. The fires should be drawn, damper, ash pit doors and fire doors closed, and everything let remain until morning. Then let the water run out, knock in the manheads, wash out the shell with a hose, enter the boiler and brush out the scale.

Q. How can water which is hard by reason of carbonate of lime or carbonate of maguesia, held in solution by carbonic acid, be rendered soft?

A. By quicklime, slacked in water and the milk stirred in, letting the sediment settle.

Q. Is sulphate of lime (plaster rock) most soluble in hot or in cold water?

A. In cold.

Q. Does incrustation thin a boiler plate?

A. Yes; when removed a thin layer of iron oxide (rust) sticks to it.

Q. What will neutralize the sulphuric and carbonic acids found in mine waters?

A. Caustic baryta for the carbonic acid and carbonates, and carbonate of soda to precipitate any dissolved lime or baryta salts.

Q. How can sulphate of magnesia be taken out of water?

A. By precipitating it with steam at 250° and filtering while hot.

Q. Is carbonate of soda good for preventing scale in stationary boilers?

A. Yes; it loosens old scales and retards the deposit of new; also kills grease.

Q. Is it good for locomotive boilers?

A. No; causes water to boil too rapidly and prime.

Q. What is the mode of action of gummy matter like starch, Irish moss, etc., in preventing incrustation?

A. They envelope the lime particles and prevent their solidifying together into a stony mass.

Q. What is the objection to their use?

A. They cause frothing and foaming.

Q. What else acts in the same way?

A. Clay.

Q. What objections to its use?

A. Its gritty particles cut the valve-seat, valves, and cylinder piston.

Q. What fault is there with tannic acid?

A. It will not act on sulphates and chlorides; it attacks the iron.

Q. What objection to acetic acid?

A. It does not affect sulphate of lime, and it eats the plates.

Q. How can tannic and acetic acids be used?

A. In tanks, the excess of acid being killed by carbonate of soda before feeding.

Q. What objection to sal-ammoniac?

A. It does not affect sulphate of lime, and it does corrode brass fittings.

Q. How is crude petroleum best applied?

A. Passed through the safety valve when the boiler is empty; then as the boiler fills, the water floats the oil and brings it into contact with the inner surfaces.

Q. Should oil be used in boilers; if so, what kind and how?

A. *The Engineer* says it believes "in a limited amount of oil, and that is *crude petroleum*, first, last, always and *only*. The quantity to be used is very, very small. We would take in every instance a boiler which had a slight amount of scales upon it, release every particle of this scale or sediment, blow it out, and keep it out, and we are sure that our readers will profit by following the directions which have been given so many times, with increased safety to themselves and an advantage in economy, and we believe it is just as applicable to a cast-iron as a wrought iron boiler, although we have not positively proved that such is the case from any actual experiment or test."

The *Scientific American* says on this subject: "The proper way to use the crude oil is to send it into the boiler through the feed water, only once a day, and only in very small quantities. One-half an ounce per day will keep an ordinary tubular boiler of fifty horse-power as clean as possible; and after a few months of regular use the shell will be found as smooth as a piece of japanned

work, provided it was not pitted at the start; and the tubes will be perfectly clean and smooth. The oil must be introduced into hot water, and for some reason it does its work better under pressure. If any 'constant feeding' of the oil into a boiler takes place, the fire seams will commence to leak, for this has been tried; there seems to be a call for only a small amount of oil, and the small amount must not be exceeded."

Q. When iron and brass are together in a boiler, which gets corroded by river waters?

A. The iron.

Q. Which do well waters containing soluble salts attack, the iron or the brass?

A. The brass.

Q. How may internal corrosion of marine boilers be largely prevented?

A. By the use of zinc, put in in slabs, say one square foot for each 20 indicated HP.

Q. What becomes of the zinc?

A. It gets corroded to oxide.

Q. How does it prevent the corrosive action on the iron?

A. It gets corroded instead of the iron by galvanic action, the zinc being the positive pole.

Q. What is a good protection against internal corrosion?

A. A very thin coating of scale or of Portland cement.

Q. What are the objections?

A. The scale is apt to crack, and the cement to be washed off by the feed.

Q. What is the principal cause in promoting explosions?

A. Corrosion, both inside and out.

Q. What causes external corrosion?

A. Negligence and ignorance; rust from the air, dripping from leaky roofs, cocks and packings; bad brick setting, letting the water rise, wet ashes touching the plates, soot in tubes, getting charged with pyroligneous and from wood fire; sulphur in the coal; galvanic action.

Q. How can tube corrosion from soot and ashes be prevented?

A. By sweeping and scraping, or blowing through with steam jets,—particularly with the so called "steam auger."

Q. How can corrosion take place from galvanic action?

A. Where brass fittings are directly attached to the shell, and the two metals are acted on by water.

Q. What is salting?

A. It is a term used in connection with marine boilers, and implying that the water gets so saturated with salt as to cause deposits of salt upon the sheets, etc., of the boiler.

Q. How much salt in one gallon of sea water?

A. That varies according to the sea; but ordinarily there is about four ounces of salt to the gallon or eight pounds of sea water.

Q. How should the scale be cleaned out from a boiler?

A. Depends somewhat upon the kind. First, the boiler should be blown off *cold*. Then, as a general thing, if the scale is very thick and hard, scaling bars and scaling hammers should be used to loosen it; it may then be hoed, raked or otherwise scraped from the surface, and removed from the shell by hoes, stiff brooms, etc.

Q. Can you give any figures as to the loss per year with a locomotive by reason of incrustation?

A. "The Railway Master Mechanic's Association estimates that the loss of fuel, extra repairs, etc., due to incrustation amount to an average of $750.00 per annum for every locomotive in the Middle and Western States."

EXPLOSIONS.

Q. What are some of the principal causes of boiler explosions?

A. Faulty material, design, construction, setting, testing, repair, care and use, bad feed, over pressure, cheap, incompetent, drunken, and unlicensed firemen.

Q. Supposing the boiler maker and setter to do their parts properly, how can the purchaser be sure that life and property are safe from damage.

A. By seeing that the safety appliances provided are of the best and are frequently tested; that the boiler is kept in good shape and never allowed to get incrusted, corroded, fouled with soot and ashes, or overheated; by get-

ting competent, experienced, sober, licensed firemen, and paying them living wages, and a monthly percentage of premium if the coal bill is kept down below a certain limit, and the steam supply is kept full, dry and regular; by putting on automatic safety appliances as a check on accident occurring through sudden illness of the firemen, and not for the purpose of enabling the hiring of cheap Jack firemen in place of competent men.

Q. What would be to your mind a proof that a boiler did not burst from over pressure?

A. That it gave way, as is very often the case, in the strongest parts.

Q. If a boiler burst by hydrostatic pressure, would the parts be thrown into the air?

A. No.

Q. Other things being equal, which is the more dangerous, a boiler having a large supply of water or one having but a small supply?

A. One having a large supply.

Q. Give a sketch of the manner of rupture of a water tube?

A. This one from the Brooklyn sugar refinery (Fig. 123).

Q. How about the electric theory of boiler explosions?

A. It is humbug. The only way in which steam can be made to generate electricity is by having the boiler perfectly insultated by glass supports, and having box-wood linings to the nozzles from which it is discharged. It is in fact

FIG. 123.—RUPTURE OF A WATER TUBE.

very difficult to get electricity from steam even when you want it.

Q. Can electricity have anything to do with boiler explosions?

A. No, unless very indirectly by lightning failing to strike whosoever was responsible for the explosion, in time to prevent his causing it.

Q. What will account for many of the mysterious explosions of boilers which stand the inspector's tests of 100 pounds

one week and go off at 50 pounds the next?

A. Unequal expansions.

Q. Suppose that it were possible to decompose the water in a boiler by contact with over heated plates; what would be the result?

A. The oxygen would attack the inside of the plates and cover them with oxide of iron, so as to stop the process very soon.

Q. Will pure hydrogen explode?

A. No, not if alone or mixed with steam: it will extinguish flame just as water will.

Q. What authority have you for such a statement as that?

A. None less than that of the great Faraday. He said in 1859 in his report to the British Board of Trade, in referrence to the superheating device in which steam was carried in contact with hot iron pipes: "I am of opinion that all is safe; i. e., that as respects the decomposition of the steam by the heated iron of the tube, and the separation of hydrogen, no new danger is incurred. Under extreme circumstances the hydro-

gen which could be evolved would be very small in quantity—would not exert greater expansive force than the steam—would not with steam form an explosive mixture—would not be able to burn with explosion, and probably not at all if it, with the steam, escaped through an aperture into the air, or even into the fireplace."

Q. Suppose that you had a locomotive boiler with 75 cubic feet of water space and 75 cubic feet of steam room, and having steam in it at 140 pounds pressure; what would be the weight of the water, and what that of the steam?

A. About 4650 pounds of water and about 26 pounds of steam.

Q. What would be the temperature of the steam?

A. About 361 degrees.

Q. Then how much higher would the water be heated in this case, than would be necessary for it to be heated in order to give off steam in the open air?

A. About 150 degrees.

Q. How many pounds of steam at a total temperature of 1200 degrees would be required to contain the heat contained

wonld take about 32 pounds of good coke or coal.

Q. Are explosions at the moment of starting common?

A. Engineer Parker says that of 24 marine boiler explosions, 19 were at the moment of starting up and 4 when the piston had reached it stroke.

Q. Do boilers often rupture quietly without explosion?

A. Yes, about as often as they burst with explosion.

Q. How would you tell whether or not a boiler was burst by reason of the plates having been overheated?

A. If all the parts could be found, the burnt iron could be readily distin guished.

Q. Can an empty boiler heated to redness be partly filled with water without danger of explosion?

A. This has been done many times, by accident and on purpose.

Q. How much water would the same amount of heat which would raise 100 pounds of iron one degree, raise to the same amount?

A. About 11 pounds.

Q. About how many pounds of steam does an ordinary locomotive boiler contain when running?

A. About 25 to 30.

TESTING AND INSPECTING.

Q. How should steam boilers be tested?

A. Testing steam boilers is best done by filling them with cold water, weighting the safety valve at the point to which it is desired to test the boiler, and firing up. Such a test is less of a strain upon the sheets than the cold hydraulic test, and less than a steam test.

Q. What preliminary examination should be made of new boilers, before filling them?

A. They should be examined thoroughly to see that nothing has been left in them.

Q. Which style of boiler is the most readily entered and inspected?

A. The plain cylindrical without flues, and having hemispherical ends.

Q. Is a tubular boiler easily inspected and tested?

A. No.

Q. What other class is particularly hard to get at?

A. Some forms of marine boilers which have tortuous and complicated passages and spaces.

Q. How about testing gauge cocks?

A. They should be frequently examined and blown off, being opened and closed gradually; and they should be ground on their seats whenever they leak.

Q. What about testing the steam gauges?

A. They should be tested every year at least, by those competent to do this work and with proper apparatus.

Q. What is the best way of testing a boiler by pressure?

A. Fill with cold water and then fire up, and let the expansion of the water put on the pressure.

Q. How about the temperature to which the water should be raised in this hot water test?

A. It should not be very high, as that prevents the inspector getting around and under the shell.

Q. When the cold water test is ap-

plied, what precaution should be taken about gauges?

A. There should be two; one on the shell and the one at the pump.

Q. What is the most reliable test?

A. The sound test.

Q. Describe it?

A. It cannot be described. A good part will sound differently when struck than a defective part will. The shell should be marked off in squares of one foot each way and each one struck; then every sheet, crown-bar, tube, stay, brace, angle iron, etc., should be rung.

Q. How must every stay and brace be?

A. Taut and sound.

CAPACITY.

Q. What is the "capacity" of a boiler?

A. The actual amount of water that it will evaporate under stated conditions.

Q. Can you tell the evaporative power of a boiler from its heating surface or grate surface?

A. No; neither the heating surface nor the grate surface of a boiler gives any indication of its evaporative power,

as their proportion to one another, and the position and angle of the heating surfaces, make great differences.

Q. About how much coal per hour per square foot of grate surface can be burned in evaporating water from and at 212°?

A. Rankine gives the following:—

	Lbs.
Slowest rate, Cornish boilers	6
Ordinary " " "	10
" " factory "	12 to 16
" " marine "	16 to 24
Quickest " complete combustion, dry coal (air through grate only)	20 to 23
Quickest rate, complete combustion, caking coal, air holes above fuel to extent of 1-36 the grate area	24 to 27
Locomotives	40 to 120

Q. That is a wide range. What may we average it for anthracite under stationary boilers?

A. 8 to 16 lbs. per hour per square foot of grate per hour.

Q. And for bituminous?

A. 10 to 20 lbs.

Q. And for locomotives?

A. 125 lbs.

Q. About how much water can be evaporated "from and at 212°" per hour per square foot of grate surface?

A. In ordinary practice, from 6 to 10 lbs.

Q. What is the theoretical maximum for good coal or coke?

A. About 14 lbs.

Q. What makes the wide range?

A. The kind of grates, kind of firing, quantity, position and condition of heating surface, kind of chimney and draft, rate of combustion, etc.

Q. About how much water per hour per square foot of heating surface can be evaporated "from and at 212°"?

A. The results of several tests which are before me run about as follows:—1.07, 2.86, 3.9, 4.04, 3.3, 2.8, 1.5, 1.2, 3.2, 3.3, 3.1. These results are so widely different that it would be hardly right to average them; they represent different kinds of coal and different types of boilers.

SO CALLED "HORSE-POWER" OF A BOILER.

Q. What is the horse-power of a boiler?

A. There is no such thing. It is the engine developes the horse-power—supposing that there is an engine, which is

not always the case. A boiler might be a 100-horse boiler with one engine, and only a 75-horse with another.

Q. Could you not make an artificial or nominal rating—say with reference to the amount of heating surface?

A. No; because boilers with equal heating surface and unequal grate recess, or chimneys, might have different capacities; and some kinds of heating surface are worth more than others.

Q. Could not boilers be rated by their grate surface?

A. No; because the heating surface, the height of chimney, etc., would influence the capacity.

Q. Is there no rough rule of practice as regards this "horse-power of boilers," by which one can tell about what boiler to get for a certain engine?

A. It is usual to allow about a cubic foot of water per hour per horse-power for a plain slide valve engine; and the ordinary rule of thumb is this:

Square feet of heating surface per H.-P.

Cylinder boilers,		9
Flue	"	12
Tubular	"	15

Q. What was Watt's rule for the so-called horse-power of wagon boilers?

A. One square foot of grate surface, 1 square yard of heating surface, $\frac{1}{2}$ a square yard of water surface, represent 1 HP.; that is, will evaporate 1 cubic foot of water per hour.

Q. Is this rule of any present use?

A. Little, if any.

Q. What "rule of thumb" for so-called HP. of tubular boilers?

A. Multiply the number of square yards of heating surface by the number of square feet of grate; take the square root, and multiply by 1.8.

Thus, supposing 40 sq. ft. of grate and 75 sq. yds. of heating surface—

$$40 \times 75 = 3000; \sqrt{300} = 54.77;$$

$$54.77 \times 1.8 = 98.586$$; or practically a "100-horse" boiler.

(Remember that there are 9 square feet in a square yard.)

Q. What is the present standard of so called horse-power of a boiler?

A. That recommended by the Judges at the Centennial Exposition was the evaporation of 30 lbs. of water per hour from feed water having a temperature

of 100° F. into steam having a pressure of 70 lbs. per square inch above the atmosphere.

That of the American Society of Mechanical Engineers is the evaporation of 34½ lbs. from and at 212°.

These two differ from one another by only about 1-30 of one per cent.

Q. What "rule of thumb" for the so called HP. of a Cornish or a Lancashire boiler?

A. Multiply square yards of heating surface by square feet of grate, and take the square root.

Q. What "rule of thumb" for so called HP. of a cylinder boiler?

A. "Divide the sectional area of the boiler by 6." (This presumably means the *lengthwise* sectional area in *square feet*)

Q. What "rule of thumb" for proportion between grate area and heating surface?

			Heating surface.	
A. For	cylinder boilers,		11 times	grate.
"	flue	"	17	"
"	vert. tub.	"	24	"
"	portable	"	26	"
"	loco.	"	30	"

Q. What is Thurston's rule for quantity of water required per *indicated* horse-power of the best engines?

A. Divide 150 by the square root of the pressure.

Thus: Suppose a Corliss engine, 75 indicated HP., to get steam at 81 lbs. boiler pressure, then it would need

$150 \div \sqrt{81} = 150 \div 9 = 16.44$ lbs. per HP.

Or

$16.44 \times 75 = 1233$ lbs. of water per hour.

For good engines (not the best) use 200 instead of 150; for plain slide valve engines, 350, so that, in this latter case, 75 indicated horse-power will need

$75 \times 350 \div \sqrt{81} = 75 \times 350 \div 9 = 2917$ lbs. of water per hour.

DUTY OR ECONOMY.

Q. What is the "duty," "efficiency" or "economy" of a boiler?

A. The comparative amount of water that it will evaporate under stated conditions.

Q. What is the "efficiency" or "duty" of a furnace for a given sort of fuel?

A. The proportion between the amount of heat which is available (or which can

be got out of the fuel into the water), and the theoretical maximum amount or total heat.

Q. Does the steam boiler utilize all the heat that is in the fuel ?

A. Not by a great deal.

Q. What causes limit the utilization by the boiler, of the entire energy of combustion ?

A. Imperfect combustion, and imperfect transfer of the heat of that imperfect combustion to the water and steam in the boiler.

Q. What are the causes of loss of heat, more in detail ?

A. Radiation from the furnace walls ; using cold air supply and too much air ; heat escaping up the chimney in the draft ; fuel going off half burned in the smoke, or dropping through the grate.

Q. How may the various losses and wastes of the boiler and engine together be apportioned ?

A. Considering all the losses from the fireman to the engine, inclusive, we may charge the chimney with 25 per cent., the fireman or " stoker " with 10 per cent., and the loss by exhaust steam

55 per cent., leaving only about 10 per cent. of the entire energy that should be got out of the fuel, accounted for by the steam engine indicator as being converted into mechanical work. This means that the boiler wastes 35 perc ent., of the entire energy; and that of the whole amount wasted by the boiler, 25-35 or 71 per cent. is wasted by the chimney, and 10-35 or 29 per cent. wasted by the fireman.

Q. How can the number be got by which to figure out the evaporation "from and at 212°"?

A. Divide 965.7 into the difference between the total heat of the steam at the observed pressure and the total heat of feed water at the observed temperature.

Q. How many cubic feet of steam will be required to supply one horse-power for one minute, supposing it be at 80 pounds, and to fall to 70 pounds?

A. About 23 cubic feet.

Q. Suppose that one pound of carbon had all its heat utilized in power; how many horse-power would it exert in one hour?

A. 5.65.

Q. How many for one minute?

A. $5.65 \times 60 = 339$.

Q. How many for one second?

A. $339 \times 60 = 20340$.

Q. How many pounds of water would it evaporate from and at 212° F. if all its heat were utilized?

A. About 15 pounds.

Q. Suppose a man were to come along and claim that he had a boiler that would evaporate 18 to 20 pounds of water per pound of coal; what would you say?

A. That he either lied or did not know what he was talking about.

Q. Why?

A. Because the highest possible is only about 13 pounds.

Q. Suppose that he put a meter on and showed you the 18 or 20 pounds fed in per pound of coal burned?

A. I would know that the meter was false, or the blow-off opened, or that the steam was about one-third water.

Q. Suppose a boiler evaporates 10 pounds of water per pound of coal: how much will that be in cubic feet?

A. If you mean 10 pounds "from and

at 212° F.," count 60 pounds of water per cubic foot for that temperature, or 1-6 cubic foot of water for each pound of coal combustible.

Q. Suppose a boiler makes steam at 70 pounds by the gauge, from feed water at 125° F.; what would that be, counted from the standard of "from and at 212°"?

A. 1.1237 times as much duty as observed with the given steam pressure and feed temperature.

Q. Can you give any figures from tests, showing the relative efficiency of fire-box and tube surface?

A. In a paper before the English Civil Engineers, the fire box was shown to do 1-5 and the tubes 4-5 of the work: this would give one square foot of fire-box about 11 times as great a value as one square foot of tube surface.

Q. Are there any experiments showing the comparative efficiency of heating surfaces arranged in different manner to meet the currents of gases of combustion?

A. The experiments of Dr. Alban and of the United States Navy have proved that a given surface arranged with the

gases at right angles to the heating surface is 30 per cent. more efficacious than when in the form of fire tubes, as usually employed.

Q. Can you give an approximate list of square heating surface per H. P. in different styles of boilers; the rate of combustion of coal per hour, per square foot of fire surface, required for that rating; the relative economy, and the rapidity of steaming?

A. Here is a table giving such data.

Type of Boiler.	Sq. ft. for One H. P.	Coal for each sq. ft.	Relative Economy.	Rel. Rapidity of Stg.	Authority.
Water-tube ..	10 to 12	.3	1.00	1.00	Isherwood.
Tubular ...	14 to 18	.25	.91	.50	"
Flue......	8 to 12	.4	.79	.25	Prof. Trowbridge.
Plain Cylinder.	6 to 10	.5	.69	.20	
Locomotive....	12 to 16	.275	.85	.55	
Vert. Tubular..	15 to 20	.25	.80	.60	

Q. Is there more economy in a large or in a small boiler; and why?

A. In a large one, per unit of power, it is cheaper in first cost, and takes less space, less brickwork in setting; has fewer

joints, parts, and pieces; costs less for repairs; has less radiating surface.

Q. What may be said on the other side of the question?

A. There is this advantage in having two boilers rather than one, that if one is crippled it leaves the other ready for work; and to a certain extent steam pressure may be carried more uniform with two boilers than with one, if the firing is done by hand.

Q. For boiling materials in tanks, etc. which takes the least fuel, high or low pressure in the boiler which supplies the steam?

A. High.

CARE AND USE.

Q. What is the first duty of an engineer in the morning when he enters his boiler room?

A. To try all the gauge cocks to see that he has enough water, and just enough; to test his safety valve by lifting it; to test all try cocks and the glass water gauge; to see that the check valves are free, the feed stop valves open, and the blow off valves tight shut, that the damper works

freely, furnace is clean, grate bars straight, and every thing about the boiler and its appurtenances is in good order; in case of inspection and repairs having been made, that no thing is left in firebox or flues; and that the upper gauge cock is open to let the air out while steam is forming.

Q. What should be done when filling the boiler with water?

A. The safety valve should be lifted in order to allow the air to escape—unless the man-hole plate was off.

Q. About how much water should you allow above the top flue for a tubular boiler of five feet diameter?

A. About six inches.

Q. How about the water line?

A. It should be kept at one fixed place all the time.

Q. What is the effect, upon the water line, of suddenly opening the throttle?

A. If the boiler has too little steam room and high pressure is carried, the water in the glass will show a higher level than there really is in the boiler.

Q. Suppose that although you are feeding in constantly, you find the

water line gradually going down; what might be the causes?

A. Leakage of the suction pipe, choking in the pipes, leakage of the valves, pump getting too hot, throwing on of too great a demand for steam, as by bursting of some steam pipe, or the throwing in of steam hammers or something like that.

Q. How can you see if the pump is working properly?

A By having a test cock upon it.

Q. Are boilers generally too large or too small for their work?

A. Too small; they are more frequently over-worked than underworked.

Q. If water will evaporate at 67° F. in a vacuum, why would not fuel be saved by evaporating by steam at that temperature?

A. Because the boiling point merely refers to the giving off of bubbles. At low temperatures the latent heat is greater than at high, so the same amount of heat is taken.

REPAIRS, ETC.

Q. What tools constitute a complete outfit for a boiler room?

A. Set of wrenches, or monkey wrench es, to take in all the attachments, and of the parts of a sectional boiler that require to be taken down or tightened up; set of shovels, rakes, pokers and slice bars, scaling bars, pries; shakers if there are shaking grates; lamps and torches; fire hose; watering-down hose; stiff brooms for sweeping out; steel wire flue brushes, and steel scrapers; also a steam auger.

Q. If a leak starts under a lap or seam around any rivet, staybolt, etc., what should be done?

A. It should be repaired at the earliest chance, to prevent corrosion of the sheet.

Q. If a flue gets leaky when it is in the head, how can that be remedied?

A. By calking; or if that will not do, by driving in a ferrule.

Q. What objection to this last?

A. It reduces the cross area of the tube that is available for passing out the gases of combustion.

Q. How about the practice of marking a leaky place while the pressure is on, and calking under lowered pressure?

A. Wrong, as the jarring is liable to start the seams.

Q. What is a good way to hold a globe valve disk squarely and properly in place while grinding to its seat?

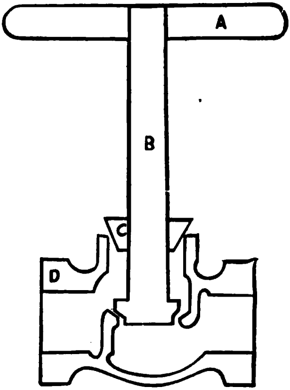


Fig. 124.

A. Turn a piece of wood as shown in the diagram* at *C*, then take the valve to pieces, as all you will need will be

*Cut by courtesy of *American Miller*.

the wheel *A*, stem *B*, body *D*, and the piece of wood with a hole bored through the center, the same size as the stem *B*.

Take the wheel off and put the piece of wood on the stem (as shown in the figure), then replace the wheel, and you are ready for work. When you want to put on new emery, simply pull the wood and all out of the body of the valve and replace as before.

Q. In patching a boiler, what precaution about cutting out the sheet?

A. The hole should be as nearly round (circular) as possible.

Q. How about cutting square holes in boilers?

A. It should never be done if possible to avoid it; but if done, the corners should be left rounded out.

Q In putting in a new sheet should it be as thick as the old one?

A. No; a trifle thinner.

Q. On which sheet should the calking be done?

A. On the new one.

Q. Which way should the lap run?

A. From the fire, if near it.

Q. How can you stop a short crack from extending?

A. By drilling a small hole at its end.

Q. What is the best way of removing flues from locomotive boilers?

A. Opinions differ; some split the forward end about one inch inside of sheet. Some, if flues are not badly scaled, turn down the bead in the fire box and drive them out; if scale has formed upon them to any extent, they take out the dry-pipe, cut off the flue end inside of the fire box sheet, turn down the bead or front end, and drive the flues into the boiler.

Q. What is the disadvantage of using a locomotive to pull flues out of locomotive boilers?

A. It strains the flue sheet, and grinds the holes out of round.

Q. How can you get great flue-pulling power without the use of a locomotive?

A. If there are only a few bottom flues to be taken out, ream out one hole, about $\frac{1}{8}$ inch, and draw the flues with a windlass of 2″ round iron, to extend across the front end and to rest upon two of the front end studs; in each end of this bar there should be one inch hole for a

$\frac{7}{8}$ inch lever; in the centre of the bar to be an eye-bolt, with chain attached. The bead is cut off both ends of the flue; it is then driven out about 6 inches and then drawn out with the windlass.

Q. Which are the harder to get out, flues expanded with the Prosser expander, or those with the roller?

A. Those with the Prosser, because of the shoulder which is formed inside of the sheet.

Q. How may old flues be cleaned?

A. By a tumbling barrel; also by a special flue cleaning machine.

Q. How do you make and use a tumbling barrel?

A. Take an old boiler and lengthen it to suit; run about 50 turns a minute, with a few hard clinkers in with the flues. The rivet heads in the boiler will be cleaned.

Qr What is about the best way of setting old flues?

A. Roll the front end, and roll and bead the back end (of locomotive flues), using a copper ferrule expanded to fit the holes in the flue. The flue to be placed in position and expanded with a roller.

Q. How much reliance can be placed upon automatic appliances, such as gongs, whistles, etc., for regulating the height of the water?

A. By the fireman, none whatever. They are to protect the boiler owner, and the community generally, from the consequences of the fireman not attending to his proper duty, from carelessness, ignorance, sudden illness or from death, etc.

Q. Will the glass water-gauge show the level of the water in the boiler?

A. Not with absolute reliability.

Q. If the lower fitting of the water-gauge glass gets stopped up, will the level shown be too high or too low?

A. Too high.

Q. How can the amount of water in the boiler be properly told?

A. By the gauge cocks ʻry cocks.

Q. How can you see whether or not the glass water-gauge shows the true level?

A. Shut off the lower gauge cock; drain the glass by the lower glass cock; shut the glass cock and open the gauge cock; if the water does not rise to the

same height as before, the water gauge is not in good condition.

Q. If the water commences to fluctuate in your glass water-gauge, how would you proceed to prove your true water level without having recourse to your gauge cocks, not knowing but they may be influenced with the same cause which affected the glass gauge?

A. Open the furnace doors to let in the generation of steam, and partly or entirely close the throttle.

Q. If a gauge glass breaks, should a new one be put in at once?

A. No; because it will be likely to break; it should be put in when the steam pressure has lowered.

Q. In case of breakage of the glass gauge what would you do?

A. If it was one of the ordinary gauges I should take an old coat or something like that to protect myself from the steam and boiling water; close the water valve first to save water; then the steam valve; (if I could not get a chance to lower the pressure), put in the new glass, open the steam valve, then the water valve and then the pet cock at the bottom.

Q. What will dissolve out the scale from gauge glasses?

A. Muriatic acid and water.

Q. What will very largely prevent the deposit of scale upon them?

A. Dipping them in glycerine before putting them in.

Q. What about the care of glass gauges?

A. They should be blown out often to remove the stuff that lines the glass tube and the mud which is apt to get in the lower connection.

Q. What precaution should be taken in swabbing out glass water-gauge tubes?

A. The swab should be of wood and covered with cloth, as if metal scratch the inside of the tube it is liable to cause it to break.

Q. What is the best way to remove the discoloration from the inside of the glass water tube?

A. Dip the swab in strong vinegar before using it.

Q. What is a good way of blowing out the water-gauge glass?

A. Have the bottom connection or

drip cock connected with a small pipe which runs under into the ash pit; and once or twice a day, at least, blow through. The current of steam cleans out the glass and the connections.

Q. Any special precaution in handling the glass water-gauge cocks?

A. The bottom one should be opened cautiously.

Q. Should the gauge glass be shut off at night?

A. Yes, if there be no watchman whose duty it is to look after the boiler.

Q. What is the danger in letting a water-gauge remain in communication with the boiler all night or over Sunday if there is no watchman?

A. If the stuffing box is leaky, there may be outside deposit of scale to prevent the height of water being seen.

Q. Should the gauge cock fitting be screwed up to stop a leak while the steam is on?

A. No, as there is danger of breaking it off.

Q. If the try cock in the ordinary fitting breaks, what should be done at once?

A. The furnace door should be opened (unless it is a wood fire) and the fire partially banked; the dampers closed, and the water allowed to blow out at the lower hole until steam shows. While this is going on a white pine plug should be made, about six feet long and of a size to fit the hole, and the hole jammed with that. Then the stick may be cut off and the end driven tight into the hole, and then tied or braced into place to keep from being blown out when the steam pressure rises.

Q. How would you repair finally?

A. Cut out the old piece, tap again and put in another pipe, or gauge cock, or whatever was needed.

Q. Suppose the bottom gauge is broken off, where should the level be carried?

A. Above the second cock.

Q Suppose the steam cock breaks off, where should the level be carried?

A. If the fireman knows his boiler, he should know about how long it takes to run the level down one gauge; then he should fill to the upper gauge and run until he thinks that the level is

nearly down to the middle one; then pump it again. Of course the gauge glass may be used, if there is one, as a sort of check upon this, but the gauge glass is not absolutely reliable.

Q. Suppose the fireman does not know his boiler and cannot tell how long it takes to run down one gauge?

A. Then he should carry the water about at the third gauge all the time.

Q. Suppose that the third gauge is broken?

A. Then the level should be kept just at the second.

Q. Suppose all three try cocks are broken and there is no gauge glass?

A. Then all three holes should be plugged up, the steam run down, the feed put well on; then the top cock fixed, then the second, then the bottom one, so as to keep the water pretty well in the boiler all the time.

Q. If you tried the gauge cocks and found no water in sight what would you do?

A. Put wet ashes upon the fire, then draw it, then open out the flue caps and let the boiler cool down.

Q. Suppose your steam gauge gets out of order?

A. If there is only one on the boiler, there should be an extra one in the boiler room for a "spare," and this should be put on at once.

Q. Is it safe to run with the safety valve alone?

A. No; not by any means.

Q. What precaution should be taken to prevent the pressure gauge from freezing?

A. The drip with which it should be furnished should be opened.

Q. What may be the causes of low water?

A. Insufficient feed, foaming or leakage.

Q. Suppose that you know that the water is too low, but do not know how low it is; what should be done?

A. The fire should be drawn, or else choked with ashes or earth; then the furnace door left open, as well as the ash pan door and the damper.

Q. What should be done if the water should be found to be dangerously low?

A. The fire door should be opened

and the fire should be drawn as soon as possible.

Q. What should *not* be done in case of low water?

A. The safety valve should not be touched, nor cold water thrown in.

Q. What should be done if the steam pressure gets too high?

A. If there is sudden increase of pressure, the damper should be closed and the feed put on, *unless there is low water as well.* If the pressure is dangerous, the furnace doors should be opened, and the ash pan doors shut.

Q. What should be done in case the the engine stops suddenly and lessens the demand upon the boiler?

A. The furnace door should be opened, the fire covered with fresh fuel, and the damper turned.

Q. What should *not* be done?

A. The safety valve should not be touched.

Q. Suppose a fire breaks out in the building and it is necessary to abandon the boilers; what should be done?

A. If there is time the boiler should be filled with water, the fire drawn, the

fire doors closed, the safety valves fastened open, the throttle left open and the engine valves left open.

Q. After the fire what should be done if the boiler remain uninjured, even although the fittings were destroyed?

A. The water should be run out if if there was any likelihood of its freezing.

Q. Suppose a Hancock inspirator gets choked up with scale; how can it be cleaned out without spoiling the inner surface?

A. By plugging it up at one end and filling it with muriatic acid and water, one-half of each, and letting this eat out the scale.

Q. Suppose you have an injector that is too large for the boiler and which cannot be worked to less than its maximum capacity; how should you feed in order to get the nearest approach to a continuous feed?

A. Feed a very little at a time, very often.

Q. How can you regulate the amount of water that the feed pump sends to the boiler?

A. If it is belt driven, put a churn

valve in a pipe leading from the discharge back to the suction, or put an air valve back of the check in the suction.

Q. Suppose your pump will not work?

A. Keep the water level above the second gauge, stop the engine, bank the fire, then go to work about fixing the pump. (This is of course in case there is no other pump and no injector)

Q. How can you find out where there is a stoppage in the suction pipe?

A. Tap it with a hammer all along its length. The full part of the pipe sounds differently from the empty portion.

Q. How often should a boiler be blown off?

A. That depends on the kind of water, the amount of forcing that the boiler gets, and the uses to whirl it; to which it is applied. As a general thing, if the boiler rests Sunday it may be blown off from the bottom once a week, *when cool.* If in constant use and scaling very fast, it may be partially blown off from the bottom, once a day or oftener, to remove deposit; and if there be light floating material it may be blown off at the surface when desirable; always remember-

ing that every time a boiler is blown off, while in service, the heat which it took to raise the water blown off to the temperature at which it is blown off, is *lost*. More *heat* may be wasted in blowing off than in letting scale form; but the safety and durability of the boiler demand that scale be prevented from forming.

Q. What can be said of blowing down between high and low water?

A. Sometimes beneficial; but wastes a great deal of heat and fuel.

Q. Will blowing off remove scale completely?

A. It only helps, even if properly done. Done while the boiler is hot, it may tend to burn on the deposit.

Q. What is the disadvantage of feeding in front and blowing off through the steam pipe?

A. There is more liability to mud accumulating in the rear end of the boiler.

Q. Where the feed water contains salts, which blow off is the best, the surface or the bottom?

A. That at the surface.

Q. What precaution should be taken in blowing off?

A. To open the gauge-cocks in order to prevent a vacuum being formed. (This is not necessary if there is an automatic air inlet valve.)

Q. How long should the surface blow off be used at a time upon large boilers?

A. Not over a minute.

Q. What is a hard patch?

A. Ono regularly put upon the sheet by cutting away the old material, and riveting the patch in the regular way, chipping and caulking as for new work.

Q, What is a soft patch?

A. One simply put on over the old material, being held by countersunk screw bolts, and having a mixture of red lead and iron borings between the patch and the main sheet.

Q. What objection to a soft patch?

A. It makes too much thickness of iron between the fire and the water.

Q. What would you notice in inspecting braces?

A. Whether or not they fit tight as they should.

Q. How would you tighten a loose brace?

A. Take it out, heat it in the middle, and shorten it by jumping it upon a block of wood.

Q. What precaution with reference to the safety valve, in starting up?

A. It should be raised to see that it is in proper working order.

Q. Is there danger from raising the safety valve suddenly? If so, what and why?

A. Yes; there is danger that the whole body of water in the boiler may suddenly lift up.

Q. Is there danger to the boiler in suddenly opening the throttle and starting the engine?

A. Yes; many boilers have been known to explode at the moment of suddenly starting up.

Q. How would you tell which tubes got the best draught?

A. Put two pine plugs in two of them and see which lasted the longer.

Q. When two or more boilers are connected by feed pipes, what should be done about the stop valve upon each?

A. It should be shut off when not working, to prevent the water from escaping from one to the other.

Q. What about the condition of the ash pan?

A. It should be kept clean to protect the grate bars and keep the draft free.

Q. What is better than L's in most places about the feed pipes?

A. T's, with plugs which can be taken out so that the pipes can be cleaned out by inserting a steel rod.

Q. Can you run a Cornish or a Lancashire boiler without any grates?

A. Yes, just use the bottom of the inside flue as though it were a box stove.

Q. With what should every feed heater be provided?

A. With a pressure gauge, if it be a closed heater; and in every case with a means of finding out the temperature.

Q. In putting on a man hole plate, what should be done?

A. Any old pieces of gasket which may have been burned on to the plate or to its seat should be scraped off.

Q. Do boilers improve by being left idle, or not?

A. They deteriorate by oxydizing and corroding.

Q. If a boiler is to stand idle what should be done?

A. It should be blown off when nearly cool, and then wiped dry inside; or else it should be left quite full of water.

Q. What is the best way to clean a boiler that has got rusty inside from standing wet?

A. Scrub the rust out with a stiff wire broom; then with sal-soda and water.

Q. Suppose in going away at night, you find that your dampers below the grates leak air; what should you do?

A. Bank up the leaks with ashes.

Q. Should you leave a wood fire with the door open or closed?

A. Closed.

Q. How about the door of a coal fire in leaving?

A. It should be open.

Q. Should the pressure be kept upon boilers all night if they are not needed for steam?

A. That depends. It certainly lessens the life of the boiler to have it expand and contract each 24 hours. But then

again, this expansion and contraction tend to crack off scale.

Q. After drawing the fire what should be done with the dampers and doors?

A. They should be closed in order to keep the heat in the boiler, unless it is desired for some special purpose that it cool off soon

Q. What precaution should be taken about ashes?

A. They should not be allowed to accumulate about the water legs or other lower portions of the boiler, as they are corrosive when wet.

MISCELLANEOUS.

Q. What are the desirable qualities in a boiler?

A. Safety, simplicity, compactness, durability, cheapness, ease of repair, thorough circulation (but not through the steam space), light weight, economy in fuel, facility of examination, cleaning and repairs.

Q. Which of these is the most desirable?

A. That depends entirely upon the circumstances. Aboard ship, compact-

ness, light weight, and economy of fuel, count for more than ashore, and so on all through.

Q. About how much coal per year is used in the world for making steam?

A. About 150 million tons, worth about $375,000,000.

Q. How fast will steam at a pressure of 80 pounds to the square inch escape into the air?

A. About 1800 feet per second or 1240 miles per hour.

Q. What is the effect of introducing sal soda into the feed when the water is foaming because it is greasy?

A. It will make it foam worse for the time being, but by forming with the grease a kind of soap that rises to the surface and may be blown off, the matter is soon remedied.

Q. What causes foaming?

A. Water that is dirty, greasy or soapy, or that has soda in it; mixing salt or fresh water; too much water and too little steam room; not having enough surface at the water level to let the steam disengage without carrying water with it.

Q. Where do the scales generally lie thickest? and why?

A. Over the fireplace, and around the mud drum or blow off pipe; because there is more heat there and less circulation.

Q. What are the advantages of small flues?

A. They can be made thinner than large ones for the same pressure, and conduct heat *sooner* to the water.

Q. Why not say "more rapidly?"

A. Because after the heat has once passed through, its rate of passage is practically the same through a thick tube as through a thin one.

Q. What is the best material for locomotive flues?

A. Soft iron.

Q. Why is the central vertical row of tubes often left out in multi-tubular boilers?

A. To make cleaning easier.

Q. What objection to tubes of less diameter than 2″?

A. They are liable to get stopped up with ashes, cinders and pieces of unburned fuel.

Q. How may we increase the velocity of flow of the gases in the tubes?

A. By increasing the draft or by decreasing the area of tubes or their number.

Q. With great draft should the tubes be longer than with but slight, or not; and why?

A. Longer, because there should be more opportunity given for the gases to remain in contact with the walls of the tube, to give out their heat.

Q. What is the life of a steel fire-box or a locomotive boiler burning bituminous coal?

A. About 250,000 miles or 10 years. (Wootten).

Q. What is the life of a steel fire box in a locomotive engine burning anthracite?

A. Wootten places it about 200,000 miles or 8 years; Ely 6 years.

Q. Where does a locomotive dry pipe give out first, and why?

A. Near the front flue sheet, by reason of the mechanical action of the water.

Q. Should much reliance be placed upon self-acting apparatus?

A. Not by the fireman. They are to protect the employer from carelessness of the fireman.

Q. What is the effect of temperature upon the tensile strength of wrought iron boiler plates?

A. A committee of the Franklin Institute proved in 1837 that their tenacity increased up to 550 degrees Fahrenheit; at that point it began to diminish.

Q. How should a shavings bin be protected from fire?

A. It should be of brick, and should have a steam pipe leading into it.

Q. Should the width of the water leg increase or diminish upward?

A. Increase, to give better circulation and get rid of the steam as fast as formed.

Q. Is the disengaging space for steam larger, in a cylindrical boiler, when the level is high or when it is low?

A. When it is high; because the level is always above the centre line of the boiler.

Q. Can you lead steam from one vessel and make it boil water in another?

A. Yes.

Q. Then is not this making steam raise steam?

A. Yes, but all the steam formed in the second vessel will disappear from the first, and with it as much more as is required to raise the water in the second vessel to the boiling point.

Q. How is red lead cement made?

A. Rub pure red lead with white lead ground in oil, until you have a thick putty, and soften it by pounding; keeping on pounding and rolling and adding more red lead.

Q. What should be done where this cement is to be used upon any rough faces?

A. It should be softer than for faced joints, and should have some fine iron filings mixed with it.

Q. What can be said about red lead joints?

A. They do not look neat, and are difficult to start.

Q. With what materials is a rust joint made?

A. Sal-ammoniac, iron borings, flowers of sulphur, and water.

Q. What makes a good joint for

smooth surfaces, that can be conveniently caulked?

A. Sheet copper, annealed by heating to a cherry red and plunging in cold water.

Q. What can you say about wire joints?

A. Lead wire will make a good joint, copper wire a better; it being best to have a groove in one of the surfaces that are to be brought together.

Q. What is a wire cloth joint?

A. It is made by taking wire gauze and coating it upon both sides with white lead or red lead paint.

Q. What makes a good joint for pumps or stand pipes in the holds of vessels?

A. Canvas, well covered upon both sides with white lead or with red lead.

Q. What else can be used for this purpose?

A. Pasteboard instead of canvas.

Q. What is the best color for the brick-work of a brickset boiler?

A. White, because it radiates less heat than any other color, other things being equal.

Q. What is the worst color for boiler brickwork?

A. Black, because it radiates the most heat.

Q. What is a good black paint for the iron work of a boiler?

A. Blacklead; (plumbago; graphite). Paint the iron work with blacklead ground in oil, and then when dry give a regular coat of stove polish in the ordinary way.

Q. What is a good black paint for a smoke-stack?

A. Dissolve asphaltum in turpentine at a gentle heat.

Q. How many times greater is the area is a *three*-inch pipe than *one*-inch?

A. Nine; because surfaces are to each other as the squares of their diameters.

Q. Suppose we had one pipe one inch in radius and another of three inches radius, what would be the proportions of their areas?

A. One to nine.

Q. Are the carrying powers of pipes proportionate to their areas?

A. No; large ones have proportionately greater carrying power, because the

proportion of friction is less. A three inch pipe would have more than nine times the carrying power of a one-inch pipe, because while it has nine times the cross section it has and only three times the circumference to cause skin friction.

DEFINITIONS, RULES AND CALCULATIONS.

Q. What is a diameter of a circle?

A. Any straight line passing through its centre and ending, at each side, in the perimeter.

Q. What is the radius of a circle?

A. Half the diameter.

Q. What is the circumference of a circle?

A. Its girth; the length of the line which bounds it.

Q. What is the periphery of a circle?

A. Its circumference or girth.

Q. What other name is there for circumference or periphery?

A. Perimeter.

Q How do you find the diameter of a circle having double the area of another?

A. Divide the double area by 0.7854 and take the square root of the quotient;

or multiply the diameter of the smaller circle by 1.4142.

Q. How do you find the diameter of a circle having half the area of another?

A. Multiply the diameter of the large circle by .7071.

Q. What figure encloses the most area for a given length of periphery?

A. The circle.

Q. How do you get the circumference of a circle from its diameter?

A. Multiply the diameter by 3.1416; or more roughly, multiply by 22 and divide by 7.

Q. How do you find the diameter of a circle from its circumference?

A. Divide the circumference by 3.1416; or, divide by 22 and multiply by 7.

Q. How do you get the area of a circle from its diameter?

A. Multiply the square of the diameter by .7854.

Q. How do you get the diameter of a circle from its area?

A. Divide the area by .7854 and take the square root of the product.

Q. What is an ellipse?

A. A symmetrical figure with curved

outline, and having two points or *foci*, so placed that the sum of the distances from any point in the perimeter to those *foci*, is the same as the sum of the distances from any other point in the perimeter to those *foci*.

Q. What is an oval?

A. An egg-shaped figure; generally one end larger than the other; or, if symmetrical, not having the property of the ellipse as regards its radii.

Q. How do you find the number of cubic feet of water which a cylindrical boiler will hold?

A. (1) Multiply the diameter in feet by itself and by .7854, and by the length in feet; this gives contents in cubic feet.

Or, (2) Multiply diameter in inches by itself and by .7854 and by length in feet, and divide by 144 to get contents in cubic feet.

Or, (3) Multiply diameter in inches by itself and by .005454, and by length in feet, to get contents in cubic feet. (*New*).

The three foregoing rules give the same result. Thus: boiler 60 inches diameter and 12 feet long:—

(1) $5 \times 5 = 25$.

```
   .7854
      25
   -----
   39270
  15708
 -------
 19.6350
      12
--------
235.6200 cu. ft.
```

(2) $60 \times 60 = 3600$;

```
    .7854
     3600
 --------
  4712400
 23562
 --------
2827.4400
       12
---------
33929.2800
```

```
33929.2800 ( 144
288        |------
---        | 235.62
 512
 432
 ---
  809
  720
  ---
   892
   864
   ---
    288
    288
    ---
```

(3) $60 \times 60 = 3600$;

$$
\begin{array}{r}
.005454 \\
3600 \\
\hline
3272400 \\
16362 \\
\hline
19.634400 \\
12 \\
\hline
235.612800
\end{array}
$$

Q. How do you calculate the amount of water in a plain cylinder boiler; the water line being *over* the centre line of the boiler?

A. Find the volume of the steam space, and take it from that of the whole cylinder. In order to get the volume of the steam space, multiply the length of the boiler (say in inches), by the area (say in square inches), of the circular segment above the water line. The area of this segment can be got from a table of areas of segments of circles, in which the diameter of the circle is assumed as one, and the comparative height of the segment is called the *versed sine*. The area of this unit segment is multiplied

by the square of the actual diameter of the circle.

Thus:—If a plain cylinder boiler, 14 feet long and 60 inches in diameter, was filled to within 12″ of the top; then as 12 is .20 of 60, we look for the segmental area opposite .20 as a *versed sine*.

It is found to be .11182. Then .11,-182 $\times$ 60 $\times$ 60 = 4225.52 sq. in., area of segment. 4225.52 $\div$ 144 = 2.93 sq. ft., area of segment. 5 $\times$ 5 $\times$ .7854 = 19.635 = sq. ft. area of whole head. 19.635—2.93 = 16.70 sq. ft. of head covered by water. 16.7 $\times$ 14 = 233.8 cubic feet of water.

Q. How do you find the safe external pressure on an iron boiler flue?

A. (1) Multiply the square of its thickness in inches by 806,300. (2) Divide the product by flue diameter in inches. (3) Divide the quotient by three times the flue length in inches. The result will be safe working pressure in pounds per square inch.

Q. How do you find the effective heating surface of a flue boiler?

A. (1) Multiply the circumference of the shell in inches by 2 and divide by 3. (2) Multiply the circumference of

one tube in inches by its length in inches and by the number of flues. Add these products. Divide their sum by 144. Quotient is effective heating surface in square feet.

Q. How do you find the effective heating surface of a horizontal cylinder boiler?

A. (1) Multiply its circumference in inches by two and divide by three. (2) Multiply the result by 144 to get square feet of effective heating surface.

Q How do you find the effective heat-heating surface of a horizontal tubular boiler?

A. (1) Multiply the circumference of the shell in inches by 2 and divide by 3, and multiply the result by length of shell in inches. (2) Do the same thing with dimensions of one tube and multiply by number of tubes. (3) To the sum of these two products add $\frac{2}{3}$ the gross area (in square inches) of both tube sheets. (4) From the sum subtract the combined area (in square inches) of all the tubes. (5) Divide remainder by 144 to get the area in square feet.

Q. How do you figure out the heating surface of an ordinary locomotive boiler?

A. (1) Multiply length of furnace plates in inches by their height, in inches, above the grate. (2) Multiply widths of ends in inches by their height in inches. (3) Multiply length of crownsheet in inches by its width in inches. (4) Multiply the circumference of one tube in inches by its length in inches and by number of inches. Add these four products and from their sum take the area of the fire door and the cross section of all the flues. Divide the remainder by 144 and that will give heating surface in square feet.

Q. How do you find the heating surface of vertical tubular boilers such as are used in fire engines and agricultural engines?

A. Multiply diameter of fire-box in inches by 3.1416 and multiply the product by its height above grate (in inches).

(2) Multiply tube circumstance in inches by tube length in inches.

(3) To the sum of these products add area of lower tube sheet.

(4) From this sum take combined area of all tubes in square inches.

(5) Divide remainder by 144 to get result in square feet.

Q. Figure up the heating surface of a boiler 54″ diameter, 12 feet long, and having 60 three-inch tubes.

A. 54″ diameter of shell $\times 3.1416 =$ 169.6464″ circumference of shell. $169.6464 \times 12 \times 12 \div 144 = 169.6464$ sq. ft. in crown portion of shell.

$3'' \times 3.1416 \times 60 \times 2 \div 3 \times 3.1416 \times 120 = 376.992'' = \frac{2}{3}$ circumference of all tubes.

$376.992 \times 12 \div 144 = 376.992 \div 12 =$ 31.416 sq. ft. $= \frac{2}{3}$ heating surface of all tubes.

$3'' \times 3 \times .7854 = 7.0686$ sq. in. cross area of one flue.

$7.0686 \times 60 \times 424.116 =$ sq. in. cross area of all flues.

$54 \times 54 \times 7854 = 2290.2264$ sq. in. $=$ area of one head.

$2290\ 2264 - 424.116 = 1866.11 =$ sq. in. heating surface in one head.

$1866.11 \times 2 = 3732.22 =$ sq. in. net heating surface in both heads.

$3732.22 \div 144 = 25.92 =$ sq. ft. heating surface in both heads.

In convex shell	169.65 sq. ft.
In tubes	31.42 " "
In both heads	25.92 " "
Total effective heating surface	226.99 sq. ft.

Q. How do you find the collapsing pressure of a boiler flue in pounds per square inch?

A. (1) Multiply the thickness of the iron in 32ds of an inch by itself, and by 262.4. (2) Divide quotient by flue length in feet. (3) Divide this quotient by one-third flue diameter in inches.

Q. How can the piston displacement and maximum discharging capacity of a feed pump be calculated?

A. Multiply the area of the piston in square inches by its stroke in inches, and that will give the cubic inches piston displacement or maximum discharging capacity per single stroke.

If it is a double-acting pump, multiply this piston displacement per single stroke by the number of single strokes (time the number of double strokes).

If it is a single acting pump multiply the piston displacement per single

stroke by the number of its double strokes.

USEFUL TABLES.

The table on page 371 gives, for the more common combustibles, the air required for complete combustion, the temperature with different proportions of air, the theoretical value, and the highest attainable value under a steam boiler, assuming that the gases pass off at 320°, the temperature of steam at 75 lbs. pressure, and the incoming draft to be at 60°; also that with chimney draft twice and with blast only the theoretical amount of air is required for combustion.

The table on page 372 is calculated for shells of various internal diameters, and two or three different thicknesses of iron for each internal diameter; three different tensile strengths of iron being quoted, as also both single riveted and double riveted seams. It will be found convenient, and is safe where the actual tensile strengths come up to the mark on the iron or on the bill. Of course if iron is stamped 50,000 and is really only 40,000, the table will not apply.

TABLE OF COMBUSTIBLES.*

KIND OF COMBUSTIBLES.	Air re-quird	Temperature of combustion.				Theoretical value.		Greatest value under boiler.	
	In pounds per pound of combustible.	With theoretical supply of air.	With 1½ times the theoretical supply of air.	With twice the theoretical supply of air.	With three times the theoretical supply of air.	In lbs. of water raised 1° per lb. of combustible	In lbs. of water evap. at 212°, with 1 lb. comb.	With chimney Draft.	With blast theoretical supply of air, 60°; gas, 320°.
Hydrogen	36.60	5750	3860	2880	1940	62032	64.20		
Petroleum	15.43	5050	3515	2710	1850	21000	21.74	18.55	19.90
Carbon: Charcoal, Coke, Anthr.	12.13	4580	3215	2410	1650	14500	15.00	13.30	14.14
Coal: Cumberland	12.06	4900	3350	2550	1730	15370	15.90	14.28	15.06
" Coking Bituminous	11.73	5140	3520	2680	1810	15837	16.00	14.45	15.19
" Cannel	11.80	4870	3330	2540	1720	15080	15.60	14.01	14.76
" Lignite	9.30	4700	3210	2490	1670	11745	12.15	10.78	11.46
Peat: Kiln dried	7.68	4470	3140	2420	1660	9660	10.00	8.92	9.42
" Air dried, 25 per cent. water	5.76	4000	2820	2240	1550	7000	7.25	6.41	6.72
Wood: Kiln dried	6.00	4080	2910	2260	1530	7245	7.50	6.64	7.02
" Air dried, 20 per cent. wat.	4.80	3700	2670	2100	1490	5600	5.80	4.08	4.39

* Authority of Babcock & Wilcox.

Safe P essur: for B ilers Safety Factor of Six.

Internal Diameter of Shell in Inches.	Thickness of Iron.	Longitudinal seams. Single Riveted. Tensile strength of Iron.			Longitudinal seams. Double Riveted. Tensile strength of Iron.		
		45000 Lbs.	50000 Lbs.	55000 Lbs.	45000 Lbs.	50000 Lbs.	55000 Lbs.
		Pres.	Pres.	Pres	Pres.	Pres.	Pres.
	Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
36	1-4	[illegible]	116	127	125	139	152
	5-16	[illegible]	145	159	156	174	191
38	1-4	99	110	121	119	132	145
	5-16	123	137	151	148	1[illegible]4	184
40	1-4	94	104	115	113	125	138
	5-16	117	130	[illegible]	140	156	172
42	1-4	89	[illegible]9	109	107	1 9	131
	5-16	112	124	136	134	149	163
44	1-4	85	[illegible]5	104	102	114	125
	5-16	107	118	130	128	142	156
46	1-4	82	91	100	98	109	120
	5-16	102	113	125	122	136	150
48	1-4	78	87	96	94	104	115
	5-16	98	109	120	118	131	144
	3-8	118	131	144	142	157	173
50	1-4	75	83	92	90	100	110
	5-16	94	104	115	113	125	138
	3-8	112	125	138	134	150	166
52	1-4	72	80	88	86	96	106
	5-16	90	100	110	108	120	132
	3-8	108	120	132	130	144	158
54	5-16	87	96	106	101	112	122
	3-8	104	116	127	120	134	14[illegible]
	7-16	121	135	148	140	156	172
60	5-16	78	87	95	94	104	114
	3-8	94	104	115	113	125	138
	7-16	109	121	134	131	145	160
66	3-8	85	95	104	102	114	125
	7-16	99	111	121	120	133	146
	1-2	112	117	138	137	152	167
72	3-8	78	87	96	94	104	115
	7-16	91	102	1 2	110	122	134
	1-2	102	117	128	125	140	153

STANDARD DIMENSIONS OF WROUGHT IRON PIPE.

Inside diameter.	Thickness.	Actual inside diam'r	Inter'l circumfer	Exter'l circumfer	Lgth sq ft inside sur	Lgth sq ft outside sur	Internal area.	External area.	Length contai'g 1 cu. ft.	Weight pr ft. of length.	Threads per inch of screw.
Inches.	Inches.	Inches.	Inches.	Inches.	Feet.	Feet.	Inches.	Inches.	Feet.	Lbs.	
1/8	0.068	0.270	0.848	1.272	14.15	9.44	0.0572	0.129	2500.0	0.243	27
1/4	0.088	0.364	1.144	1.696	10.50	7.075	0.1041	0.229	1385.0	0.422	18
3/8	0.091	0.494	1.552	2.121	7.67	5.657	0.1916	0.358	751.5	0.561	18
1/2	0.109	0 623	1.957	2.652	6.13	4.502	0.3048	0.554	472.4	0.845	14
3/4	0.113	0.824	2.589	3 299	4 635	3.637	0.5333	0.866	270.0	1.126	14
1	0.134	1.048	3.292	4.134	3.679	2.903	0.8627	1.357	166.9	1.670	11 1/2
1 1/4	0.140	1.380	4.335	5.215	2.768	2 301	1.496	2.164	96.25	2.258	11 1/2
1 1/2	0.145	1.611	5.061	5.969	2.371	2.01	2.038	2.835	70.65	2.694	11 1/2
2	0.154	2.067	6.494	7.461	1.848	1 611	3.355	4.430	42 36	3.667	11 1/2
2 1/2	0.204	2.468	7.754	9.032	1.547	1.328	4.788	6.491	30.11	5.773	8
3	0.217	3.067	9.636	10.996	1.245	1.091	7.388	9.621	19.49	7.547	8
3 1/2	0.226	3.548	11.146	12.566	1.077	0 955	9.887	12.566	14.56	9.055	8
4	0.237	4.026	12.648	14.137	0.949	0.849	12.730	15.904	11.31	10.728	8
4 1/2	0.247	4.508	14.153	15.708	0.848	0.765	15 939	19.635	9.03	12 492	8
5	0.259	5.045	15.849	17.475	0.757	0.629	19.990	24.299	7.20	14.564	8
6	0.280	6.065	19.054	20 813	0.63	0.577	28.889	34.471	4.98	18.787	8
7	0.301	7.023	22.063	23.954	0.544	0.505	28.737	45 663	3.72	23.410	8
8	0.322	7.982	25.076	27 096	0.478	0.444	50.039	58.426	2.88	28 348	8
9	0.344	9.001	28.277	30 433	0 425	0 394	63.663	73.715	2.26	34.077	8
10	0.366	10.019	31.475	33.772	0.381	0.355	78.838	90.762	1.80	40.640	8

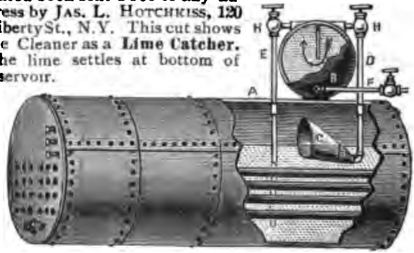
TABLE OF THE CAPACITY OF CISTERNS AND TANKS, COMPUTED IN BARRELS OF 31½ GALLONS.

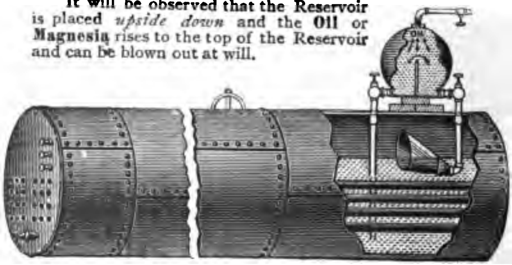
Depth.	DIAMETER IN FEET.															
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	23.3	33.6	45.7	59.7	75.5	93.2	112.8	134.3	157.6	182.8	209.8	238.7	269.5	302.1	336.6	373.0
6	28.0	40.3	54.8	71.7	90.6	111.9	135.4	161.1	189.1	219.3	251.8	286.5	323.4	362.6	424.0	447.6
7	32.7	47.0	64.0	83.6	105.7	130.6	158.0	188.0	220.6	255.9	293.7	334.2	377.3	423.0	471.3	522.2
8	37.3	53.7	73.1	95.5	120.9	149.2	180.5	214.8	252.1	292.4	335.7	382.0	431.2	483.4	538.6	596.8
9	42.0	60.4	82.2	107.4	136.0	167.9	203.1	241.7	283.7	329.0	377.7	429.7	485.1	543.8	605.9	671.4
10	46.7	67.1	91.4	119.4	151.1	186.5	225.7	268.6	315.2	365.5	419.6	477.4	539.0	604.3	673.3	746.0
11	51.3	73.9	100.5	131.3	166.2	205.1	248.2	295.4	346.7	402.1	461.6	525.2	592.9	664.7	740.6	820.6
12	56.0	80.6	109.7	143.2	181.3	223.8	270.8	322.3	378.2	438.6	503.5	572.9	646.8	725.1	807.9	895.2
13	60.7	87.3	118.8	155.2	196.4	242.4	293.4	349.1	409.7	475.2	545.5	620.7	700.7	785.2	875.2	969.8
14	65.3	94.0	127.9	167.1	211.5	261.1	315.9	376.0	441.3	511.8	587.5	668.4	754.6	846.0	942.6	1044.4
15	70.0	100.7	137.1	179.0	226.6	279.8	338.5	402.8	472.8	548.3	629.4	716.2	808.5	906.4	1009.9	1119.0
16	74.7	107.4	146.2	191.0	241.7	298.4	361.1	429.7	504.3	584.9	671.4	763.9	862.4	966.8	1077.2	1193.6
17	79.3	114.1	155.4	202.9	256.8	317.0	383.6	456.6	535.8	621.4	713.4	811.6	916.3	1027.2	1144.6	1268.2
18	84.0	120.9	164.5	214.8	272.0	335.7	406.2	483.4	567.3	658.0	755.3	859.4	970.2	1087.7	1211.9	1342.8
19	88.7	127.6	173.6	226.8	287.0	354.3	428.8	510.3	598.9	694.5	797.3	907.1	1024.1	1148.1	1279.2	1417.4
20	93.3	134.3	182.8	238.7	302.1	373.0	451.3	537.1	630.4	731.1	839.3	954.9	1078.0	1208.5	1346.5	1492.0

INDEX.

An asterisk or star (*) denotes one or more illustrations.

In looking for any subject having more than one important word, look first for what appears to you to be the principal word; and if you do not find it under the initial letter of that word, try under that of the other. The only exception is the word "boiler," which is not in this index as a first word. Where it occurs elsewhere it is designated simply by the letter "b." Valve is also abbreviated "v."


H
H
E
D
F
A
B
C


OIL

THE

PUMP CATECHISM.

OPINIONS OF THE PRESS.

"If you own a pump this is the volume you ought to own."—*Phila. Press.*

"The work has only to be read by any intelligent steam user to be appreciated, and should be in the hands of every engineer."—*American Engineer.*

"This book will undoubtedly be found of service to those having the care of pumps. We do not know of anything published covering the same ground."—*Am. Machinist.*

"It would only be tiresome to our readers to attempt a 'review' of this important book, and we believe we do them and the author the best service by saying 'GET IT AT ONCE.'"—*Cincinnati Artisan.*

"For those engaged in the operation of this class of machinery, the little volume will be of considerable interest, and may save much vexation and trouble."—*Electrical World.*

"What we are inclined to consider the best of all of the works of Robert Grimshaw is the volume just received, entitled 'Grimshaw's Pump Catechism.'"—*Millers' Review.*

"No engineer, steamfitter or plumber should be without one."—*Sanitary Engineer.*